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MINE RESCUE WORK AND ORGANIZATION

BY
H. F. BULMAN
AND
FREDERICK P. MILLS

UNIVERSITY OF TORONTO
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MINE RESCUE WORK

AND

ORGANIZATION

A RESCUE BRIGADE WEARING AEROPHOR BREATHING APPARATUS.

[*Frontispiece.*

MINE RESCUE WORK

AND

ORGANIZATION

BY

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WITH A FOREWORD

BY

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President of the Institution of Mining Engineers

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FOREWORD

By Colonel W. C. Blackett, C.B.E.

President of the Institution of Mining Engineers.

In commending this book to both learners and learned in what is called Mine "Rescue" work as a ready means of reference to the general state of knowledge of the subject, I would like to take the opportunity of impressing on all concerned, how important it still remains that all the ordinary means of seeking access to and exploring a mine after any accident, or in case of need, should be intelligently used and exhausted before any call is made upon such jeopardous appliances as breathing dresses in poisonous gases.

There is no better method, for instance, of recovering a mine after an explosion than the old-fashioned way of taking in fresh breathable air, carefully tested by the small bird and safety lamp, and resort should only be made to the breathing dress, worn by an expert, when a well-defined purpose appears which can be described in terms of locality and distance.

It should be as rare that men should be required to dive into bad air in a breathing dress, as it is to dive into water in a similar appliance.

For the extinction of fires also, the object should be clearly defined before the breathing dress should be called upon, and then, if possible, the smoke helmet should be used, for it cannot be too much

impressed upon every one concerned, how absolutely useless it is to advance into smoke, because sight is practically impossible, and the chances are the fire may burn the dress before the eye can see the flame.

I have always contended that the term "Rescue" dresses was misleading to the public, who, hearing all the exaggerated talk of their use, have conceived the vain idea that all that was required after a colliery explosion, in order to save many lives, was to have very large numbers of men trained in the use of breathing appliances.

By all means let us have them when wanted, and let us have them good, but do not let us place ourselves in a false position.

Of all the appliances described in this excellent little volume, such as lamps, telephones, pumps, hose, canaries, pit tracings, and breathing dresses, which is of the least importance, or which would first be done without?

So I would, while not disparaging the breathing dress in its proper place, earnestly advocate the study of the co-ordinated uses of all the other appliances by men with a finely balanced sense of "pitmatics," and I live in hope that, with the almost certain safety which must result from the compulsory application of stone dust in coal mines, the need for so much "Rescue" work and so very many "Regulations" may recede.

AUTHORS' PREFACE

At collieries with their liability to the occurrence of fires, explosions, falls of stone and other accidents Rescue Work in the general meaning of the term is no novelty.

With the advent, however, of self-contained Breathing Apparatus and other new appliances within recent years, Rescue Work has become associated more particularly with the use of these appliances.

As they are useless without a body of men trained in the knowledge and use of them, an elaborate organization has been developed with the object of providing both these Rescue Appliances, and also Brigades of picked and trained men ready to turn out night and day to any call for their services, within easy access of every colliery in the United Kingdom.

From figures published in the last report of the Chief Inspector of Mines, it may be gathered that there are in the United Kingdom at the present time about 50 Central Rescue Stations and more than 6,000 picked and trained men, organized in Rescue Brigades. These numbers will be increased, as Government Regulations have time to fructify.

As yet no book on the subject has been published. With the present volume, the Authors have endeavoured to supply this want.

With respect to the illustrations which are such an important feature of a book of this kind, they wish to express their great obligation to Instructor Francis J. Johnston, of the Elswick Rescue Station, Newcastle-upon-Tyne, who has prepared them.

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BY

H. F. BULMAN, F.G.S., M.I.M.E., A.M.I.C.E.

AND

Sir R. A. S. REDMAYNE, M.Sc., F.G.S., M.I.M.E.

LONDON: CROSBY LOCKWOOD & SON.

MINING

I

SELECTION OF MEN FOR RESCUE WORK

THE selection of the right type of man and his adequate training are essential to the proper performance of the difficult and often dangerous operations which are required in Mine Rescue Work.

Obviously he should be the happy possessor of a sound mind in a sound body, a man of temperate and healthy habits, of determination and self-control, and one who is accustomed to hard and strenuous work. Nervous and excitable men are quite unsuitable.

He should take up the work from choice, having a liking for it, and not under compulsion, and he should receive encouragement from his employer.

With respect to age, the limits of 23 to 45 have been recommended by the Mine Rescue Apparatus Committee.[1] This should not preclude men younger than 23 receiving the training, if they are physically fit. Mining students will be all the better for it,

[1] The Mine Rescue Apparatus Research Committee was appointed by the Advisory Council for Scientific and Industrial Research, on the suggestion of the Home Office, in 1917, and consists of—
Mr. William Walker, C.B.E., Chief Inspector of Mines.
Mr. Henry Briggs, O.B.E., D.Sc., A.R.S.M., M.I.M.E.
Mr. John Haldane, M.D., LL.D., F.R.S.
It has published two reports, the first dated February 14, 1918, and the second June 1920.

though they may not be enrolled as members of brigades; and 45, though the limiting age for joining, should not be so for retiring. Beyond this age, there are many men who may continue to be useful and efficient members.

A man of normal size and breathing capacity is to be preferred, because self-contained breathing apparatus is designed for the average man, and by its mechanical construction is confined within fixed limits.

The qualifications specified in the Government Regulations are coolness and powers of endurance and knowledge of underground work.[1] Evidently a knowledge of underground work is an advantage, and every Rescue Brigade should include at least one good "pitman" in the technical sense of that word, that is, an expert in pit work, preferably one holding an official position, such as overman, or deputy, or master shifter. Such men are likely to make the best leaders or captains of brigades.

All candidates must be certified to be medically fit. A form of Medical Certificate is appended. The new Regulations, 1920, provide also for a physical test, and leave it to the discretion of the Superintendent of the Rescue Station or of the Captain of the Brigade to reject unsuitable men. This is certainly desirable.

The ERGOMETER is a convenient apparatus for this physical test.

The Cycle Ergometer.

The Cycle Ergometer was designed by Professor Martin, F.R.S., of the Lister Institute. This Apparatus (see Fig. 1) consists of a bicycle frame elevated on a stand, but the back wheel is replaced by a heavy iron wheel connected by gearing and

[1] See Reg. 18 and 25, Gen. Regs., July 1920.

chain to the pedals in the ordinary manner. A linen strap is fixed round the circumference of this wheel, similarly to a brake strap, and the two ends of it are connected to two spring balances which indicate the tension. The resistance of the brake can be adjusted by a screw arrangement for tightening or loosening it. The circumference of the brake-wheel

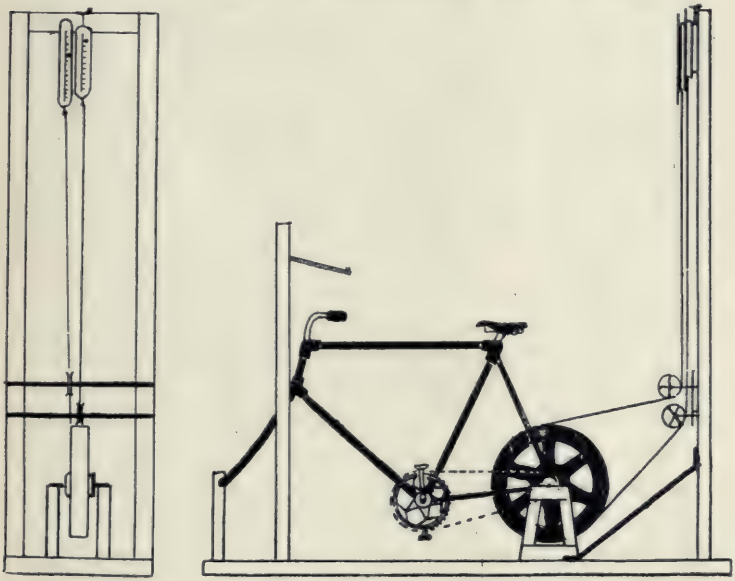


FIG. I.—MARTIN'S CYCLE ERGOMETER.

is approximately $5\frac{1}{2}$ feet. The gearing of the machine is $3\frac{1}{4}$ to 1; the periphery of the wheel travels 18 feet for 1 revolution of the pedal. The work done in turning the brake wheel equals its peripheral speed in feet per minute multiplied by the difference in tension on the two ends of the belt. The peripheral speed in feet per minute equals the speed of the pedals in number of revolutions per minute multiplied

by 18 feet. Therefore if the number of revolutions of the pedals are (say) 50 per minute, and the difference in tension of the springs is (say) 8—4=4 lb., the work done in foot-pounds will be $18 \times 50 \times 4 = 3{,}600$ foot-pounds.

By this Apparatus a man can be tested with regard to his capacity for vigorous exertion. The rate of his pulse, and condition of his breathing are observed before the test; immediately at the end of a given amount of exertion; every 5 minutes for 20 minutes after; and finally an hour later.

The main distinction between a vigorous man and one who is unfit for Mine Rescue Work is in the character of the recovery from strenuous conditions. There should be no trembling, and the breath should be easily regained.

It is probable that the factor which more than any other determines the capacity of a man to make and to endure physical exertion is the functional power of the heart. As an indication of this the breathing is a very reliable index.

The heart and the lungs must act in accord.

The lungs bring oxygen to the blood, and the heart drives the blood to the muscles doing work. A man's capacity for hard muscular work depends on the rate at which oxygen can be absorbed by the blood in the lungs, and the rate at which the oxygenated blood can be delivered to the muscles. (See Second Report of the Mines Rescue Research Committee.) By physical training a man may improve the capacity of his lungs for absorbing oxygen into his blood. Recent investigations have proved that men in good physical training, accustomed to hard muscular work, like miners, have the power of taking in oxygen into their blood during exertion more rapidly than men who lead

sedentary lives and are not in good training. Men in good physical condition can do more work, measured in foot-pounds, on the same amount of air breathed. They utilize the oxygen more efficiently.

When breathing ordinary air, during exertion, their expired air contains a much higher percentage of CO_2, and a lower percentage of oxygen than that of men who are not in training.

When wearing breathing apparatus, men who are not in good training often derive much benefit from the increased proportion of oxygen in the air they inhale. The percentage of CO_2 in their expired air is much higher when they are breathing this enriched air, than when they are breathing ordinary air.

Men in good training, on the other hand, receive no benefit from breathing this enriched air, and the percentage of CO_2 in their expired air remains much the same as when breathing ordinary air.

Thus the relative percentages of CO_2 contained in the air which a man exhales, during exertion, when breathing normal air and when breathing oxygen is a test of his physical fitness. Dr. Briggs has applied this method successfully to the testing of men for the Army.

When muscles are insufficiently supplied with oxygen, they produce and give off to the blood Lactic acid instead of CO_2.

Very excessive muscular exertion causes the blood to be flooded with Lactic acid.

"This acid acts just like CO_2, on the respiratory centre, but unlike CO_2 it is not rapidly removed from the blood by the lungs. As a consequence, intolerable panting is produced, and the exertion is brought to a speedy end . . . With more moderate exertion the blood supply to the muscles

can be properly maintained, so that little or no Lactic acid passes into the blood." (See Second Report Research Committee.)

The method of carrying out a physical test with the Ergometer is as follows :—

The person to be tested sits on the Ergometer at rest, and breathes ordinary air, drawn through a meter ; he exhales into a Douglas Bag [1] (60-litre capacity). Thus the quantity of air used per minute by the man can be estimated, and the composition of the air which he exhales can be got from the samples taken from the Douglas Bag. A man who requires an excessive quantity of oxygen per minute, or who gives off an excess of CO_2 is unsuitable for the present types of Self-contained Breathing Apparatus.

The " respiratory quotient," which is the ratio of carbon dioxide exhaled to the oxygen consumed, is a very good basis of examination of a man for physical fitness.

According to Dr. J. S. Haldane this figure (i.e. CO_2 exhaled $\div$ O_2 consumed) under normal conditions lies between 0·7 and 1. If it is outside these limits, the man is unfit.

This test can be repeated, varying the degrees of work done.

A further test should be made on the man breathing pure oxygen instead of air. The quantity of oxygen used, the CO_2 exhaled, and the work done being known, a very substantial conclusion with regard to his fitness for rescue work can be made.

Fig. 2 gives, in the form of a diagram, the result of an actual test carried out with the Ergometer,

[1] A bag devised by Dr. C. G. Douglas (see *Journal of Physiology*, 1911, vol. 42, p. xvii, "A Method for Determining the Total Respiratory Exchange in Man," by C. G. Douglas).

showing an unusually high condition of stamina and physical fitness.

This diagram illustrates Dr. Briggs' method.

The work done in foot-pounds forms the abscissæ of the diagram, and the percentages of CO_2 in the expired air the ordinates.

The two upper lines show the percentages of CO_2 exhaled when breathing oxygen and when

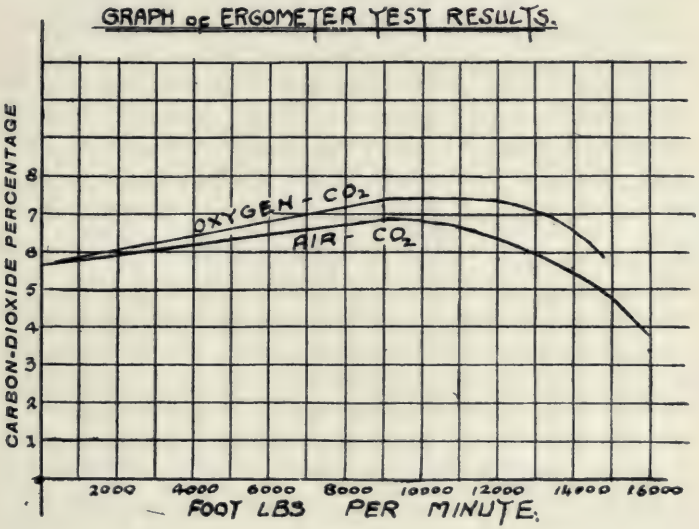


FIG. 2.

breathing ordinary air, during exertion, starting from rest and going on gradually to work of 16,000 foot-pounds per minute.

These lines are always dome-shaped curves, because the percentage of CO_2 rises from "rest" to a maximum, and then falls again. The fall is due to the dilution of the CO_2 by excess of air due to increased effort of breathing to meet the increased muscular exertion.

The foot-pounds corresponding to the maximum percentage of CO_2 indicate the work a man can do for a considerable time, his intake of oxygen being adequate to it, and is thus a measure of his stamina. Anything beyond this he can only endure for a brief period.

The difference between his output of CO_2 when breathing oxygen and when breathing ordinary air is a measure of his physical fitness.

The Research Committee consider that it is doubtful policy to keep in a Rescue Brigade (except perhaps as leader), any one whose crest-load on oxygen is 6,000 foot-pounds or less.

" The fitness of the healthy working miner usually exceeds 75 per cent., evidently it is advisable that a permanent brigade member should also be at least as fit."

Reading the graph given as an example, the measure of the stamina is furnished by the position of the crest load. A crest of 10,000 is taken as 100 per cent.

A simple and useful method of expressing the fitness of a subject is to divide the crest ordinate of the " air " curve by that of the " oxygen " curve, the level of the CO_2 value at " resting " being used as a datum for the measurement.

The attached graph shows 66 per cent. fitness and stamina excellent.

A man's condition after a spell of hard bodily work may show him to be unsuitable, though his medical examination may have been favourable.

First Aid.

Every member of a permanent rescue corps, and the majority of the members of colliery rescue brigades, must be trained in First Aid, and must hold the certificate of the St. John Ambulance Association or other approved Society.

Government Regulations about Rescue Brigades.

There are three ways in which a Mine may comply with the Government Regulations. (See First Report Mine Rescue Apparatus Research Committee.) (1) It may be connected with a neighbouring Rescue Station maintaining a resident brigade. (2) It may be connected with a Station at which there is no resident brigade, the brigades being altogether formed of employees of the mines. (3) It may be unconnected with a Rescue Station, the whole work of training men and maintaining the necessary apparatus being undertaken at the mine.

"Instructing brigades, practising trained men and maintaining apparatus, are specialized operations which can be conducted more efficiently at a Central Station than at individual mines."

Central Rescue Stations within easy reach of the surrounding Collieries supply the best organization. The mine must be in telephonic communication with the Station, and not more than 10 miles distant from it, as the crow flies.

According to the Annual Report of the Chief Inspector of Mines for 1919 (the most recent available), there were 610 mines served by 14 Central Rescue Stations under the Regulations of May 1914, and 553 mines with 1,263 Rescue Brigades and 35 Central Rescue Stations under the Regulations of 1913. From these figures it may be gathered that the number of men trained for Mine Rescue Work at that date was about 6,500. As a picked body of trained men who devote themselves to the arduous work of Rescue in colliery disasters, they deserve to be held in high esteem.

According to the Regulations, a large colliery employing more than 1,000 men underground, if

it depends on itself, must maintain not less than four Rescue Brigades of five men each, or twenty trained men. If it is attached to a Central Station where there is a permanent Rescue Corps, it must maintain five trained men at the colliery to supplement the rescue corps.

A permanent Rescue Corps must consist of not less than six men, or if the total number of underground employees at all the mines served by the Station exceeds 15,000, eight men.

If depending on itself therefore, a large colliery must have 20 trained men amongst its employees. Alternatively, it must be attached to a Central Rescue Station, when it will be able to call upon the services of a Central Rescue Corps of six or eight men, and its own five trained men working at the colliery.

A medium-sized colliery employing from 700 to 1,000 persons underground must maintain three brigades (fifteen men), or, if attached to a Central Station, three trained men to supplement the permanent Rescue Corps.

Where the underground employees number 250 to 700, two brigades are required (ten men), or three trained men in addition to the permanent Rescue Corps. Where there are less than 250 employed underground, either one Brigade (five men), or one trained man, when the services of the Rescue Corps are available.

Collieries employing fewer than 100 men may be exempted from these Regulations by the Secretary of State, if they have acquired the right to call on a Central Rescue Station.

Station Officers.—There are required also at every Station, competent Officers to take charge of the Station and to train a Rescue Corps or Rescue Brigade.

The New Regulations (1920) provide as follows :—

"At Stations maintaining a permanent Rescue Corps : if total number of underground employees at mines served by the Station does not exceed 15,000, two ; if the number exceeds 15,000, three.

"At Stations not maintaining a permanent Rescue Corps—If the total number of Brigades required to be provided at the mines served by the Station does not exceed 50, two ; does not exceed 100, three ; exceeds 100, four."

The qualifications of a Station Officer are set out in the First Report of the Mines Rescue Research Committee as follows :—

"By the term 'competent person,' we wish to be understood an Officer capable of taking full charge of the Station, conversant with the use and adjustment of the appliances, able to give instruction in subjects prescribed in training men in Mine Rescue Work, and qualified to drive the motor car at the Station. These persons should either reside at or adjoining the Station or have their houses in telephonic communication therewith."

Dealing with the same matter in their Second Report they say—"To possess the character, knowledge and status desirable in the holder of a position of this responsibility predicates a standard a good deal beyond a bare acquaintanceship with the use of the appliances at the Stations, and, in future, before an instructor is appointed, we think that his qualifications in this respect should be carefully scrutinised."

Of 519 men who have been trained at a large Central Rescue Station, 456, or 87 per cent. of them, have belonged to the class of colliery officials, mostly overmen and deputies. The other 64, have come from various grades of underground labour, hewers and stone-men being in the majority.

For permanent Rescue Corps, naval men of 12 years' service have proved themselves to be "second to none," which is due, doubtless, to the admirable system of discipline and training which they have enjoyed in the Navy.

The qualifications required of candidates, and the conditions of their employment, at an important Central Rescue Station are set out in the Appendix.

II

TRAINING

With regard to training, it is laid down in the Regulations that the course shall consist of :—

(A) Instruction as to (1) breathing apparatus, (2) methods of reviving men, (3) reading of mine plans, (4) the properties and detection of poisonous gases.

(B) Practices—not less than 12 in number, with breathing apparatus. In the case of men coming from mines where smoke helmets are kept, two additional practices with smoke helmets shall be given.

The Practices shall comprise the following operations :—

(*a*) Raising by means of a rope and pulley a weight of 56 lb. to a height of 6 feet.

(*b*) Walking continuously at a fair pace for half-an-hour.

(*c*) Building and removing temporary stoppings of stone, brick, sandbags, brattice cloth, or other materials, and carrying the materials required for the same over a distance of at least 10 yards.

(*d*) Removing débris in confined spaces as representing the clearing of a fall of roof.

(*e*) Setting timber or other roof supports.

(*f*) Carrying, pushing, or pulling on a stretcher a live person or dummy body weighing 150 lb. along the length of the gallery, and through an opening 2 feet high by 3 feet wide and 4 yards long.

(*g*) The rapid establishment of telephonic communication.

In accordance with these regulations the following scheme is in force at some large stations, where both liquid air and compressed oxygen apparatus are in use and also smoke helmets. The scheme is the outcome of considerable experience, and is giving satisfactory results.

The training occupies 14 days, which are spread over 14 consecutive weeks, and the period of each daily training is about 5 hours.

Lesson 1.

A copy of Home Office Mines and Quarries Form No. 72 (see Appendix) is given to each man, and attention called to the schemes of training and practice therein laid down.

The team is conducted through the Station and its working explained, commencing with the *Duty Room*, where their attention is called to the entry of all reports and messages, and the use of the telephones ; and the Occurrence Book containing a daily record of all the work of the Stations.

In this tour of the Station they are shown, and some explanation is given to them, about the motor cars and their equipment ; the motor fire engine ; the oxygen and liquid air dresses ; how cleaned and charged ready for use ; the electric charging stand for charging batteries ; canaries and their use, and the proper care of them ; the liquid air plant ; the

oxygen and oxygen pump ; vacuum pump for evacuating the space between the casings of the liquid air bottle ; the gas testing room, containing the Oldham Apparatus for detecting firedamp—the effect of carbon monoxide on canaries, and of carbon dioxide on an oil flame ; smoke helmets with 180 feet of hose pipes and telephone attachment—its sphere of utility ; the training gallery ; the drying room, where breathing bags are dried after washing, and also wet hose.

Then the men are made to wear the mouthpiece and nose-clip for 60 minutes, and afterwards to carefully clean them, including the flexible tubes both inside and outside by washing them in a preparation of Lysol (1 : 100).

Fire Drill is given—running out of hose, fixing standpipes, different kind of connections, care of hose, etc., etc., and a short lecture on the Smoke Helmet.

The men are encouraged to ask questions on any matter that has not been thoroughly understood. (This applies to every lesson.)

At this first lesson they are asked to choose a man amongst them as Captain. He should be a man having a good knowledge and experience of mining, and preferably one holding an official position, such as Overman or Deputy.

Lesson 2.

On arrival at the Station, the men report themselves to the Duty Man and give the name of the colliery from which they come ; then go direct to the dressing room and await orders. This procedure is carried out at each lesson.

Wear breathing dress with mouthpiece and nose-clip, but without the valve joints being connected,

for one hour. During the first 30 minutes of this period they receive Squad Drill, and then an explanation of the breathing dress, illustrated from a chart and from the apparatus worn by a man.

The apparatus should be so explained that each man may be able to visualize in his mind and to go through each detail in consecutive order.

After taking off the mouthpieces and dresses the men are shown how to clean them properly, and to re-assemble ready for use again.

Questions are then asked on instruction given.

The men should be told to bring suitable clothes to wear in the gallery, as they will require them for the next lesson. These clothes are taken away from the Station after each practice.

Lesson 3.

In the event of any member of a team being absent and less than 5 being present, the number must be made up from the Station Staff. To avoid this inconvenience, as the Station Staff is fully occupied with other duties, it is a good plan to have eight men on each team coming in from the collieries.

The Regulations limit the number present at each practice to not less than five, nor more than eight.

Work to be done.—Wearing the Oxygen Self-contained Breathing Apparatus; walk for thirty minutes at the rate of 3 miles an hour, in correct order, viz., 2, 3, 4, 5, 6, 7, 8, 1. This rate is equivalent to 88 yards a minute. A suitable distance is measured, and watch kept that the pace is not exceeded.

Rest of five minutes, and the condition of each man noted.

In the event of wet weather the practice is either

carried out in the covered part of the Station, or on equivalent work in the training gallery.

Lecture on exploration underground.

Practice with Smoke Helmet and Hand Pump in Station Yard (see details of Smoke Helmet Drill, page 37).

" Squad and Section Drill."

The Captain of the team is instructed to assemble his men in " Open Order—Stand at ease."

No instruction is given with the men standing in disorderly fashion round the Officer.

Lesson 4.

Wearing the liquid air or Oxygen Self-contained Breathing Dresses, charged to last one hour—walk for thirty minutes at a pace of 2 miles an hour (about 60 yards a minute). Gauge readings to be taken each quarter-hour if Oxygen Self-contained Breathing Dress is worn. Condition of men carefully noted at end of the half-hour. Five minutes rest.

The team is taken to the gallery, and work as follows :—

Carry, push, or pull on stretcher a live person or dummy body weighing 150 lb. along the ways of the gallery three times.

Raise by means of a rope and pulley a weight of 56 lb. to a height of 6 feet ten times.

Apparatus cleaned and re-assembled under skilled supervision.

Lecture on Liquid Air Apparatus, and Oxygen Self-contained Breathing Dress.

Fire Drill.

Lesson 5.

Work in gallery in ordinary air for 1½ hours :—

(1) Make four complete circuits of the gallery.
(2) Set timber (as instructed) and brattice cloth.
(3) Carry bricks over a distance of 10 yards.
(4) Build stoppings with bricks.
(5) Replace bricks in original position.
(6) Raise weight fifteen times.

Clean and re-assemble apparatus.

Lecture explaining the various types of respirators and revivers in use at the Station and their purpose; the use of ropes as a guide in smoke-laden atmospheres; and the organization and conduct of a Rescue Team at an underground fire at a colliery.

Lesson 6.

Lesson on construction and use of following apparatus, explained by actual demonstration :—

(*a*) Oxygen Breathing Dress.
(*b*) Liquid Air Breathing Dress.
(*c*) Pulmotor, Lungmotor, and Oxygen Reviving Apparatus.
(*d*) Artificial respiration in conjunction with (*c*). Schaefer's and Sylvester's methods.
(*e*) Use of Salvator. Oxygen Cylinder.

Lecture on the process of breathing, and the quantity and quality of respired air with and without self-contained breathing apparatus.

Mouthpieces and nose-clips are worn during part of this lecture.

Afterwards wear breathing dress in gallery in poisonous fumes for sixty minutes.

Lesson 7.

1½ hours training in gallery in fumes.
Half-hour walking at 3 miles per hour.
Clean and assemble apparatus.

Lecture on properties of Mine Gases—mode of Occurrence and means of detection.

Lesson 8.

Two hours training in gallery in fumes.

Clean and re-assemble apparatus, Smoke Helmet and Hand Pump Drill in fumes.

Lesson 9.

Work for two hours in gallery in fumes as follows :—

(1) Walk and crawl along gallery for half an hour.
(2) Set timber to instructions.
(3) Carry and hang brattice cloth.
(4) Use Salvator on several men.
(5) Carry, push, or pull on a stretcher a live person or dummy weighing 150 lb. along the length of the gallery, and through an opening 2 ft. by 3 ft. by 4 yards long.
(6) Carry 150 bricks in lots of ten over distance of at least 10 yards and build wall.
(7) Take down props and brattice cloth, and restore neatly to original place.
(8) Pull weight twenty times.
(9) Return bricks to original places.
(10) Removing débris in confined spaces may be practised if time permits.

Lecture on possible defects of Oxygen Self-contained Breathing and of Liquid Air Apparatus, and the accompanying dangers.

Lesson 10.

Oxygen Self-contained Breathing Dress worn in gallery in fumes for two hours.

Clean and re-assemble same.

Establishment of telephonic communication.

Use of portable telephones in a mine after a disaster.

Equipment of Rescue Car and Pump Car.

Lecture on protection of collieries from fire.

The men are asked to see that provision is made at their collieries as follows :—

(*a*) Telephonic communication to nearest rescue station established at convenient places at colliery.

(*b*) Suitable road for Motor Fire Engine.

(*c*) Suitable road to pond or reservoir, and a good foundation for engine when working.

N.B.—Each motor pump weighs 5 tons ; is 20 ft. long, 6 ft. 9 ins. broad, and 8 ft. 9 ins. high.

(*d*) A plan should be kept showing position of ponds and hydrants at the colliery, and the pressure and quantity of water available at these sources.

The members of the team should make themselves acquainted with this plan.

(*e*) Hydrants, standpipes, and hose should be inspected weekly, and kept in good order, ready for immediate use.

(*f*) Frequent practices with a hand pump and hose, or standpipes and hose, will ensure their being in working order.

(*g*) For petrol fires or electrical fires a suitable pump charged with Carbon Tetrachloride (Pyrene) should be kept in readiness.

If Liquid Chemical Fire-extinguishers are used, see that they comply with the Board of Trade Test, in which the cylinders are tested to 350 lb. pressure.

Lesson 11.

Lecture—Mine Gases—their physiological effects on the system. Demonstration of the "Caps" on flame of safety lamp when firedamp is present.

Use of Birds and Mice for detection of Carbon Monoxide demonstrated practically—also how birds should be carried by the advance squad.

Carbon dioxide and Blackdamp—effect on the flame of oil lamp.

Wear Liquid Air Apparatus for ninety minutes in fumes.

Lesson 12.

Test of two hours in hot and irrespirable atmosphere doing the complete work as set out in previous lessons.

Lecture on signalling, followed by practice.

Clean and re-assemble apparatus.

A copy of the code of signals is attached, p. 22. On the back of the card is a form of Record of the Oxygen used during a practice.

Special notice to be taken of the condition of each man after each practice. If a man is (1) dizzy, (2) tired, (3) exhausted, (4) has a headache, the cause should be investigated whether due to the man or the apparatus.

The pulse, temperature, and respirations of each man should be taken immediately before and after the practice, and thus a satisfactory deduction of his condition may be made.

Lesson 13.

Practice with Liquid Air Apparatus for 120 minutes in fumes.

Lecture on Mine Plan Reading and Exploration Work underground.

CODE OF SIGNALS.

Electrical Signalling.	Signalling between Members of a Brigade.	Signal.
"Distress" or "Help wanted"	"Distress" or "Help wanted"	ONE ring or ONE hoot
(*If* NO ANSWER *is given to a call, "Distress" is to be understood.*)		
"Not understood" or "Repeat the message"	"Halt"	Two rings or Two hoots
"No"	"Retire" ..	THREE rings or THREE hoots
"Yes," or "All right," or "All's well"	"Advance" ..	FOUR rings or FOUR hoots
To "ring up" or to "ring off"	To call attention..	FIVE rings or FIVE hoots

Acknowledgment of Signal to be given by replying the Signal acknowledged.

RECORD SHOWING OXYGEN USED.

No.	Name.	Time (Gauges read every Fifteen Minutes).									Total Amount of Oxygen used.
1											
2											
3											
4											
5											
6											
7											
8											
9											

Name of Team..... *Date*.....

Oral examination of men to test their knowledge of Rescue Work and Apparatus generally.

Lesson 14.

(1) Two hours in fumes, wearing Oxygen or Liquid Air Dress, using Salvator and Canaries, and carrying out operations specified in Regulations (see Appendix).

Gauge readings to be taken at intervals of fifteen minutes, each man reading his own Gauge, and the Station Officer or Captain verifying it.

The condition of each man to be noted carefully, as in Lesson 12.

(2) Signalling Test.
(3) Reviving a "gassed" man.
(4) Smoke Helmet and Hand Pump Test in fumes.

The Lectures given in one instance are arranged under the following heads :—

(1) The Proto Apparatus and Compressed Oxygen.
(2) The Aerophor Apparatus and Liquid Air.
(3) Various types of self-contained Breathing Apparatus.
(4) Causes of failure of Breathing Apparatus.
(5) Respiration.
(6) Mine gases—Properties and means of detection.
(7) Mine gases—Physiological effect on the system
(8) Smoke Helmets and Respirators.
(9) Resuscitation and Reviving Apparatus.
(10) Treatment of Carbon Monoxide poisoning.
(11) Underground fires and explosions.
(12) Rescue Work organization and Mine recovery.
(13) Mine Plan Reading.
(14) Training of Rescue Brigades.
(15) Equipment of Mine Rescue Stations.

At some Stations a copy of each lecture is given to each man undergoing training. He can then study it at his leisure ; and his knowledge can be tested by oral examination at the following practice. It is a custom to be recommended.

On completing their training, the team should be told whether they have proved satisfactory or not, and a note to this effect should be made on the daily attendance report sent to the Colliery Manager.

A Form of Daily Report as filled up in actual practice is appended, and also a Form of Record of the complete training. These are required by the Regulations.

A Form to be signed by the Colliery Manager authorizing the men to attend the Station for training is also found useful, and an attendance card recording the date and number of practices attended.

At some Stations, when a member of a Colliery Rescue Brigade has completed his three months' training satisfactorily, he is given a Certificate of competency (see form attached).

The training of the Permanent Rescue Corps residing at a Station is similar, except that its members are always engaged in training. The Certificate is not given to them until they have been twelve months in the Corps, with a view to ensuring the highest standard of efficiency.

No. ..... **RECORD OF TRAINING.** .....*Station.*

Miner's Name—Surname.....*Christian Names*.....

Address.....*Occupation*.....

Employer.....*Pit* .....

Particulars of Certificates (Ambulance and others).....

.....

FIRST COURSE:

Medical Examination.....*Date*.....19....

No. of Practice.	Date of Practice.	Character of Practice.	Condition of Miner after Practice.	Initials of Instructor.
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				

Has this man full confidence in the apparatus ?.....

Would he make a good rescue man ?.....

Result of Examination.....

Certificate issued.....*Signed*.....STATION OFFICER.

Date completed.....19....

FORM OF DAILY REPORT BY CAPTAIN OF TEAM.

Place : Training Gallery. *Date :* November 6, 1919. *Time :* 2.20–4.20.
If Underground : Time Left Surface.....Time Returned Surface.....

No.	Ref. No.	Surname.	Christian Names.	Type of Apparatus.	Time Worn, in Minutes.	Oxygen or Liquid Air used.	Remarks.
1	517	Cox	Ben	Proto	120	115	
2	520	Cunningham	J. M.	,,	,,	100	
3	519	Petrie	J. W.	,,	,,	85	Apparatus worked satisfactory
4	527	Lawson	J. M.	,,	,,	100	
5	529	Moody	Wm.	,,	,,	105	
6	518	Jones	W. M.	,,	,,	80	
7	528	O'Neill	Hy.	,,	,,	80	

NOTE.—The Practice should be carried out in every detail to Brigade Instructions. The following report should describe the nature of the Practice and the condition of each man after Practice. If anything abnormal is observed it should be stated whether it is due to defect of the apparatus or the man himself.

REPORT :

We were in the gallery to-day for 2 hours in sulphur fumes. The team transported 150 bricks from one end of the gallery to the other (a distance of 15 yards) over the top of the staging. We then carried a person around the gallery on a stretcher a few times. We then each pulled the weight 25 times. Cleaned up gallery for rest of period. After the practice the team reported well and in good condition.

Countersigned H. GARWOOD, *Station Officer.* *Signed* HENRY O'NEILL, *Capt. in charge.*

TRAINING OF COLLIERY BRIGADES.

Name of Colliery.....

Names (in full).		Occupation.	Address (in full).
Surname.	Christian Name.		

REMARKS :—

All of these men have been medically examined.

(*Signed*).....
COLLIERY MANAGER.

.....19..

ATTENDANCE CARD.

.....19..

Name of Colliery.....

Mr......*attended*.....*training at*

.....*Station.*

Remarks :

(*Signed*).....
STATION OFFICER.

N.B.—This slip must be given up to the Colliery Manager.

CERTIFICATE OF COMPETENCY.

No. ....

Name in full :

.....

.....

Address .....

.....

.....

Date issued.....

Trained at :

.....

Station.

No......

This is to certify that .....

a member of the permanent Rescue Brigade, having passed a Course of Instruction, is thoroughly competent to take part in Rescue Work, in accordance with Coal Mines Act, 1911, *Part IV, Sec.* 85, *General Regulations, May* 19*th,* 1914.

Signed.....

OFFICER IN CHARGE.

Date.....19....

Quarterly Practices.

The Regulations of May 19, 1914, laid it down that after being reported to be efficient, each man should undergo at least one practice each quarter year. In the Regulations of 1920 it is enacted that :

> " Every Rescue Corps shall, after the completion of its training, undergo at least six practices underground in mines with breathing apparatus every year, and at least one such practice in every quarter."

The purpose of these underground practices is to make the Rescue Men aware of the behaviour of the Apparatus under conditions (e.g., climbing inclines) which involve hard respiratory exertion, to accustom them travelling underground roads of all kinds with apparatus, and to bring the men of the Permanent Rescue Corps and the Brigademen employed at the colliery into contact with each other.

These practices should be organized so as to resemble as nearly as possible what would be required in case of an actual call for the services of the Brigade.

The following is a scheme, set out in some detail, which will suffice to show what is required.

Arriving at the colliery, the Rescue Team shall unload the Rescue Apparatus from the Car and place same in readiness in a room at the surface of the mine as a Headquarters for the purpose. (The New Regulations of 1920 enact that such a room shall be provided and maintained exclusively for Rescue and Aid purposes at every colliery.)

The Colliery Manager shall see to the calling in of the Colliery Team to this Headquarters, and also appoint some qualified person to attend to the

Ambulance Room, and have everything in readiness. He shall also call up a Medical Man to stand-by operations.

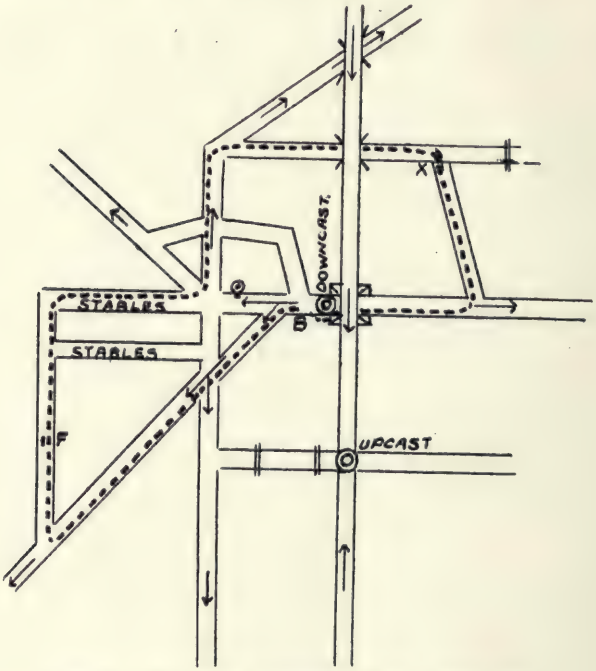


FIG. 3.—PLAN OF WORKINGS TO BE EXPLORED.

TRAINING PRACTICES.

Scale—1 inch = 50 yards.
B .. Base of operations.
..... Course to be traversed by Brigade wearing Self-contained Breathing Apparatus.
F .. Fall of stone. 15 minutes to be spent here clearing a fall of stone.
X .. Man to be found here "gassed" and injured. Team to treat and carry him to base of operations. Part of the road traversed should be on an incline.

He shall also confer with the Rescue Brigade Superintendent as to the appointment of men to

descend with the first party and the work to be accomplished.

An underground base shall be established, and Rescue Appliances taken to that point. The first squad shall test the Apparatus thoroughly, and proceed from the base to do a prescribed amount of work which shall be given in writing to the Captain of the Team, along with a plan of the workings to be traversed. The second reserve squad shall then put on the apparatus and stand-by at the base, ready to turn on the oxygen in case of an emergency. The nature of the work to be performed should vary at each practice. The following programmes of work are recommended as complying with the conditions which are often met with in mine disasters.

Practice 1.

Base to be established near the pit bottom, and all Rescue Appliances taken there.

Plan of workings to be explored. (See Fig. 3.)

The work to be performed in 1½ hours.

The Life-lines should be used and signals practised.

Birds, safety-lamps, salvators, stretcher, and electric hand lamps should be carried.

Team to return to surface with appliances within two hours.

Practice 2.

Base to be established and necessary equipment taken there.

The team to set off on a prescribed route, marking the way with chalk in the usual fashion, and continue walking for thirty minutes.

Remain at the point reached and clean up roadway.

The "reserve" party to search for the "lost" party by following chalk marks. One man is found "injured." Treat, and whole party return carrying "injured" man on stretcher to base.

Time wearing Apparatus, 1½ hours.

Practice 3.

Base to be established quarter mile inbye. Install Portable Telephones. Put on and test Apparatus. Carry hand-pump and accessories to a "fire," one hundred yards from base. Get to work on "fire." Work at "fire" for half-an-hour. Return to base and make up equipment to return. Time wearing apparatus, 1½ hours.

Practice 4.

Base to be established and equipped. The Team to put on Apparatus to go in search of six men. These six men to be previously set at various points immediately off the main road, the nearest to be within 200 yards of the base. The rescue team to effect the rescue of these men, who shall carry a tag stating the nature of his injuries. Time wearing Apparatus, 1½ hours. Part of the distance traversed should be on an incline.

At the end of his preliminary training each colliery man is given (in the Northern Coalfield) a training book or register, a small cardboard-backed book, easily carried in the pocket. This book bears the man's name and address and the name of the colliery where he is employed, and on the inside of the cover the following notes are printed :—

The member is to be examined every year by the Colliery Doctor, and entry made to say that such an examination

MEDICAL CERTIFICATE.

Name .....

Age ..... *Date of Birth* .....

Occupation .....

Colliery .....

General Condition and Appearance, including Eyes, Nose, Ears, Teeth and Tonsils :—

.....

.....

.....

Previous History of any Illnesses, Fits, Accidents, etc. :—

.....

.....

Present Condition of

Lungs .....

Heart .....

Kidneys .....

Etc. .....

Whether Ruptured ? .....

If an Ambulance Man ? .....

Habits .....

Remarks .....

.....

.....

.....

Date ..... *(Signed)* .....

MEDICAL OFFICER.

has been made as per detailed medical certificate on back (see form, p. 33), and that he is a fit and proper person to be a member of the Brigade.

The Colliery Manager to make application to the Chief Officer to send member for Quarterly Training, giving dates convenient.

The Register must be brought by each member, and will be filled in and returned to them by hand.

This will act as a receipt for attendance.

This register is issued only to Colliery Members who have completed their original course of training at the Central Rescue Station.

In this register are entered particulars of each practice subsequent to the original training. A copy of it is kept at the Station.

This register stamps its possessor as a qualified member of a Rescue Brigade, and in the event of a colliery disaster, on showing it, he would be allowed to pass the cordon of police, and to proceed to Rescue Headquarters.

When arrangements have been made at the Station for a Quarterly Training, due notice is sent to the Colliery Manager on the Form (attached), and he informs the members of his colliery.

At each central station there is kept a complete list of the collieries it serves, and the number of persons employed at each colliery. Thus the official in charge can see whether he has the right number of men trained as required by the Regulations. A Colliery Manager may ask to have extra men trained, and this is often done, so that at many collieries there are more than the requisite number of trained men.

On the other hand, there are a few collieries where they have been unable to obtain the required number of volunteers for rescue work.

If a Rescue Man leaves one colliery and becomes

FORM OF NOTICE OF QUARTERLY TRAINING SENT TO COLLIERY MANAGER.

Please hand Card to Members.

.....1920.

Dear Sir,

QUARTERLY TRAININGS.

Arrangements are made for .....

to present himself at ..... *Rescue Station,*

on.....*at*.....

Yours faithfully,
OFFICER IN CHARGE.

Extract from Brigade Orders.

1. Members attending at a Rescue Station come under the same Rule and Regulations as the Permanent Staff.
2. The practical work in the training gallery is of such a nature that Members should bring their pit clothes to wear on every occasion.
3. The Quarterly Training will extend over a period of not exceeding five hours. It is necessary for Members to bring sandwiches and refreshments to eat during the interval between the lecture and practical work, as no time is allowed for leaving the premises.

Name of Colliery Co.....

Name of Pit .....*No. of Men* .....

Date of Completion of Training..... 19.....

MINER'S NAME.	Ref. No.	Dates.										

If less than five men the number must be made up by a member of the Station staff and the attendance duly marked in red ink. 1, Present. A, Absent. P (in red), Attendance of Permanent Brigadesman.

employed at another, it is usual for the Colliery Manager to send notice of it to the Station Officer.

The colliery and address of each trained man is known at the Station, and a copy of his register kept there.

Lists are carried in the Rescue Cars, so that, in case of emergency, the Officer-in-charge can communicate with any man, who may be wanted.

III

SMOKE HELMET DRILL

Two men are necessary for Smoke Helmet Drill but a third man is an advantage.

Details of Smoke Helmet Drill with Telephone Attachment.

The three men shall range themselves at attention in front of the box containing the apparatus. They shall number themselves 1, 2, and 3 respectively. No. 2 shall be the Captain.

PROCEDURE FOR NO. 1.

(1) Lift lid of box, remove waist-belt, and secure same round waist.
(2) Grasp handle of bellows with right hand, and with left hand grasp the air-pipe about 4 inches from bellows.
(3) Lift bellows clear of box.
(4) Place spacing loop into grip, and hook bellows on to waist-belt.
(5) On the order from No. 2 he shall work bellows backwards and forwards with either hand.
(6) Take receiver and test it by calling to the man wearing Smoke Helmet.

PROCEDURE FOR NO. 2.

(1) When No. 1 is lifting out bellows, he shall pull out sufficient piping to allow free working of bellows.

(2) Secure knee steadying strap on No. 1, and give order to work bellows.
(3) Place telephone satchel over shoulder of No. 1 in such a manner that it will rest on same side as bellows.
(4) Connect up telephone.
(5) Supply air piping to No. 3.
(6) Assist No. 1 to work bellows if necessary.

PROCEDURE FOR NO 3

(1) Remove helmet from box, and place helmet on his head.
(2) Secure waist-belt.
(3) Tighten strap on morocco apron as soon as he feels air from the bellows entering helmet.
(4) Tuck apron inside his coat or tunic.
(5) Reply to telephone test call.
(6) He is now ready to proceed to work.

The number should be changed frequently so that each man becomes familiar with the detail of the different positions.

The object of No. 2 is to help No. 1 to work the bellows if necessary, and to keep on the watch for any danger, and decide the method of procedure if occasion should arise.

IV

PHYSIOLOGICAL DATA BEARING ON BREATHING APPARATUS AND MINE RESCUE WORK

Function of Breathing.

For the proper understanding of Mine Rescue Work and of Self-contained Breathing Apparatus, some knowledge of the function of breathing is desirable.

The intake of Oxygen, and the output of Carbon Dioxide, through the lungs, are an essential part of human life.

The Oxygen enters into combination with the hæmoglobin, or red corpuscles, of the blood, is carried by the blood to the heart, and thence through the arteries to the tissues, where it is consumed. Similarly the Carbon Dioxide comes from the tissues into the blood through the veins, which carry it to the heart, and thence through the pulmonary arteries to the lungs. The volume of Oxygen consumed is about a seventh greater than that of Carbon Dioxide given off.

The function of breathing is to bring Oxygen to, and remove Carbon Dioxide from, the blood.

Pure atmospheric air contains 20·93 per cent. of Oxygen, 0·03 per cent. of Carbon Dioxide, and 79·04 per cent. of Nitrogen.

The air expired from the human lungs, when dried, contains about 4·1 per cent. of Carbon Dioxide,

16·5 per cent. of Oxygen, and 79·4 per cent. of Nitrogen.

The Carbon Dioxide is increased about 4 per cent., and the Oxygen diminished about $4\frac{1}{2}$ per cent.

The expired air as it comes from the mouth is warmer, and contains about 6 per cent. of moisture, as compared with about 1 per cent. in ordinary atmospheric air.

A healthy man inspires about 7 litres, or 0·25 cubic foot, of air per minute during rest, but when he is doing muscular work, it may be six or eight times as much.

The volume of Carbon Dioxide given off varies from about half a cubic foot per hour during rest to 5 cubic feet during violent exertion.

The accompanying Table, p. 41, is taken from Technical Paper 82, U.S.A. Bureau of Mines. "Oxygen Mine Rescue Apparatus and Physiological Effects on Users," by Yandell Henderson and James W. Paul. It shows that a man undergoing vigorous exercise, such as he may be called upon to undergo in Rescue Work, may consume more than three litres of Oxygen per minute, and produce 3·38 litres of Carbon Dioxide.

The volume of air inspired depends on the depth of breathing, as well as the frequency or number of breaths per minute, and these vary considerably in different individuals. Besides the volume of air taken in and given out at each breath, which has been called the "tidal air," there is always some air remaining in the chest—the "residual air." The volume of "tidal air" is said to average about 20 cubic inches,[1] and of the "residual air" to range from 100 to 130 cubic inches. This "residual air" contains normally 5·6 per cent. of Carbon Dioxide,

[1] 1 cubic foot = 28·3 litres.

TABLE

RESPIRATORY EXCHANGE OF MEN UNDERGOING VIGOROUS EXERCISE.

Name of Subject.	Weight in Pounds.	Respiration per Minute.	Volume per Respiration.	Volume per Minute.	Oxygen in Exhaled Air.	Carbon Dioxide in exhaled Air.	Volume of Oxygen consumed per Minute.	Carbon Dioxide Produced.	Respiratory Quotient $\left(\frac{CO_2}{O_2}\right)$.
			Litres.	Litres.	Per cent.	Per cent.	Litres.	Litres.	
A	147	28	2·67	75	17·60	3·30	2·50	2·47	0·980
B	197	27	2·29	62	16·71	4·14	2·11	2·56	0·980
C	185	33	2·33	77	16·98	4·10	3·04	3·15	1·037
D	150	27	2·51	68	16·24	4·98	3·19	3·38	1·060
A man standing at rest	—	17·1	0·612	10·4	—	—	0·328	0·264	0·804

and, however the body is occupied, it requires this normal proportion to be kept constant. The proportion varies with different individuals, but 5·6 per cent. is the average for men. Any rise in it, whether due to increased exertion, or increased body temperature, or increased quantity of Carbon Dioxide in the air inspired, at once stimulates the body to harder breathing in order to reduce the proportion to the normal.

Breathing is regulated from a nervous centre situated in the lowest part of the brain, and this nervous centre is acutely responsive to the CO_2 saturation of the blood passing through it.

The respiratory nervous centre does not appear to be sensitive to variations in the proportions of Oxygen. A man may breathe air deficient in Oxygen, without being aware of it, until he falls unconscious.

" From the point of view of the user of Breathing Apparatus, it is enough to remember that excess of CO_2 induces deep and slow, and Oxygen-want quick and rather shallow breathing. Shortage of Oxygen takes effect much more quickly than CO_2 excess, since the body has practically no storage capacity for Oxygen, while it has a great deal for Carbon Dioxide."—Second Report Research Committee.

According to the latest teaching of physiologists, it is the concentration of Carbon Dioxide in the blood, that under normal conditions, when resting, governs the action of breathing, any increase above the normal causing laboured breathing, and any fall relaxing the effort of the lungs.

In its bearing on Self-contained Breathing Apparatus, this fact indicates the vital importance of the purifier in removing the Carbon Dioxide from the expired air. No apparatus is safe if the purifier

is not capable of removing efficiently the Carbon Dioxide produced.

Danger of Increased Temperature.

The danger of increased temperature may be seriously aggravated also by this part of the Apparatus. The chemical action which takes place within the purifier between the caustic alkali and the Carbon Dioxide and moisture in the expired air gives rise to a great deal of heat. Very hot air, especially if it contains moisture, causes a painful, burning sensation in the throat and air passages.

The Research Committee (First Report, 1918) says that an Apparatus should be regarded as unsatisfactory if the wet bulb temperature of the inspired air exceeds 105° Fahr. (40½° Cent.) under the temperature conditions commonly met with in the mine.

Excessive heating is one of the difficulties which designers of breathing apparatus have to overcome.

This danger of a hot purifier arises not only from the temperature of the inspired air, but also from its effect on the body temperature of the wearer.

Experiments have proved that when the wet bulb temperature exceeds 80° Fahr. the body temperature of a man working in it is apt to rise rapidly to a dangerous extent. In a dry atmosphere a man can work at a much higher temperature than this, so long as he perspires freely and the vapour from his skin is removed by moving currents of air. The evaporation from the skin keeps the body temperature from rising. But if this evaporation is stopped by unsuitable clothing, or by a still hot atmosphere saturated with moisture, the body temperature is likely to rise rapidly to a dangerous degree. Dr. Haldane has published the figures below, based

partly on direct observation and partly on calculation, to give a rough idea of the rise in body temperature with various wet bulb temperatures in still air.[1]

Wet Bulb.	Rise in Body Temperature in 15 Minutes.	
Temperature, Degrees Fahr.	Rest, Degrees Fahr.	Moderate Work, Degrees Fahr.
70	0·0	0·0
80	0·0	0·6
90	0·3	1·5
100	1·2	3·0
110	2·4	5·0
120	4·5	9·0

With the wet bulb much above 80° Fahr. a man cannot remain long at work, as his temperature will soon rise.

Rise in body temperature has also the injurious effect of increasing the output of Carbon Dioxide, and thus tends to laboured breathing.

"The effect of rise of body temperature on the breathing during muscular exertion is very distressing."—*Dr. Haldane.*

Observations made some years ago (in 1911) on healthy men wearing Breathing Apparatus of various types in the experimental mine of the University of Birmingham at Bournbrook, conducted by Dr. Fraser Harris, showed that in all cases there was a rise of body temperature. In an irrespirable atmosphere with a wet bulb temperature of 80° to 85° Fahr. the greatest increase in body temperature observed was 2° Fahr., but with a wet bulb temperature of 90° Fahr. and higher, in a respirable atmosphere

[1] See *Trans. Inst. Min. Engineers*, vol. 48, 1914, p. 556.

the rise amounted to between 2·5° and 2·8° Fahr. All the men perspired profusely, and in every case lost weight, the greatest loss being experienced naturally in the hottest and moistest atmosphere.

The action of the heart was accelerated in all cases, the lowest increase noticed being sixteen beats and the highest fifty-eight beats per minute. In all cases, however, the heart had resumed its normal beat within fifteen to twenty minutes after the cessation of the test.

The heated condition of the inspired air from the purifier produced pharyngeal catarrh, which sometimes persisted for more than a week.

When the temperature of the wet bulb thermometer is over 85° Fahr. the wearer is much more rapidly overcome by a feeling of tiredness and lassitude, and consequently is unable to perform work over a long period. The temperature of the wet bulb is an important guide in determining the length of time men should be employed in rescue work.[1]

A perfect breathing apparatus should lower, rather than raise, the temperature of the wearer.

Deficiency of Oxygen.

An adequate supply of pure Oxygen is not less important than the effective removal of Carbon Dioxide. Under the varying conditions of Mine Rescue Work an adequate supply, as the figures quoted show, ranges from about $\frac{1}{4}$ litre per minute to more than 3 litres.

A recent instance of the danger of a deficient supply of oxygen occurred during the Rescue Work following on the explosion at Podmore Hall Colliery Staffs.

Hugh Doorbar, the Captain of one of the Rescue

[1] See *British Medical Journal*, vol. 2, 1911.

Brigades, lost his life when engaged in the work of exploration in the Seven Feet seam, and wearing the Proto Apparatus.

It was found that this was due to a deficiency of Oxygen arising from a leaking main valve and a faulty reducing valve in the apparatus he was wearing.[1]

The idea that the breathing of pure Oxygen, or almost pure Oxygen, is harmful, is quite wrong.

"It is only when air containing over 80 per cent. of Oxygen is breathed continuously for over two days that evil effects make themselves felt."[2]

Want of Oxygen is a danger of a most insidious kind, because as a rule a man does not realize it, but thinks he is all right, until he suddenly loses control of his limbs, or, in some cases, becomes unconscious. It affects the brain and mental powers like strong alcoholic drink. A man loses his faculties of judgment and self-control, and his senses fail.

The symptoms are very similar to those that attend the breathing of Carbon Monoxide. This gas has a strong affinity for the hæmoglobin of the blood—a much stronger (240 times) affinity than Oxygen has—and it therefore enters into combination with the hæmoglobin to the exclusion of the Oxygen. It deprives the body of Oxygen, and naturally the symptoms shown are the same as those that accompany a deficiency of Oxygen.

It is a wise rule that the Oxygen supply in self-contained breathing apparatus should not be less than two litres a minute. This quantity will keep a man safe, though it will not enable him to undertake very vigorous exertion

[1] See Home Office Report by Mr. Walker, the Chief Inspector of Mines, issued July 1920.

[2] See Second Report Research Committee.

A consideration of the imperative needs and the delicate adjustments of the human body emphasizes the difficulties to be overcome in the design of a breathing apparatus thoroughly adequate for Mine Rescue Work.

It is a prudent provision that in such work a brigade of no fewer than five men under a competent leader should work together.

Effects of Breathing Carbon Dioxide.

Carbon Dioxide is a gas frequently encountered in Mine Rescue Work, and the effects of breathing it should be known. Two to three per cent. of it can be breathed for a considerable time without serious effects, as the frequency of respiration can adjust itself to maintain normal conditions in the blood. Four to 5 per cent. causes panting and laboured breathing. As the proportion increases to 7 or 8 per cent., giddiness and pains in the head are also felt, but on removal to fresh air recovery comes quickly, and little or no after-effects are experienced. At 10 per cent. lights are extinguished, a useful warning that the atmosphere is dangerous to breathe. Higher percentages produce unconsciousness; but even though a man has been lying unconscious in such an atmosphere for some time, he may recover with proper treatment. It is useful to remember that breathlessness starts long before there is any serious danger.

Effects of Breathing Carbon Monoxide.

As already pointed out, the effects of breathing Carbon Monoxide are much more serious. It is a cumulative poison, entering into the blood, from which it has to be eliminated before recovery can be assured.

The extent of the saturation of the blood is due not only to the percentage of the gas present in the air inspired, but also to the length of time during which it is inspired.

The volume of blood in an average man is three litres (5·2 pints), and it is capable of absorbing 600 cubic centimetres, or one pint, of Carbon Monoxide or of Oxygen, when it is said to be saturated with either gas.

It has been estimated that with 0·1 per cent. of Carbon Monoxide present in the air breathed, a man during exertion, such as walking, will get his blood 50 per cent. saturated in half-an-hour. With 0·2 per cent. of the gas this would take place in a quarter of an hour, and with 1 per cent. in about three minutes.

At 50 per cent. saturation paralysis of the limbs sets in, accompanied by loss of consciousness on exertion.

Treatment of Men "Gassed" by Carbon Monoxide or Carbon Dioxide.

With regard to the treatment of "gassed" persons in mines, the first thing to remember is that no case, however serious it may at first appear, should be regarded as hopeless. A person overcome by CO_2 is much more easily revived than one overcome by CO. The reason of this has been explained; and the treatment for CO poisoning must necessarily be of a more assiduous and exacting nature.

The skin of a person overcome by CO_2 is of a dusky bluish hue, while in the case of CO it is of a fresh pink-like appearance. This symptom serves as a rapid guide to the mode of treatment to be adopted.

In the treatment of persons rendered unconscious by breathing CO_2, it is only necessary to restore the

function of breathing, and the blood will quickly do the rest. But in CO poisoning, even though breathing be revived by artificial means, yet recovery depends entirely on the power of the patient's blood to carry the Oxygen to the tissues. If the blood has become 50 per cent. saturated with CO, the elimination of the poison is naturally a slow process, and artificial respiration with the use of pure Oxygen has to be continued persistently, sometimes over a long period.

In both cases the mischief is due to the starvation of the tissues of Oxygen, and the administration of Oxygen is a valuable aid to recovery. Where possible pure Oxygen should be given.

Artificial respiration by Schaefer's method, and the administration of pure Oxygen from a Reviving Apparatus will, in the case of CO_2 gassing, effect a permanent cure in a short period.

With CO, however, the same treatment has to be applied over a longer period, and at the same time precaution should be taken to prevent lowering of the body temperature, which is due to the small quantity of Oxygen being carried to the tissues.

Warmth can be supplied by the application of hot-water bottles, placed between the feet of the patient and up to the fork of the legs, and also on the outside, from the feet to the armpits.

A caution should be given on the indiscriminate use of Alcohol. Alcohol only tends to reduce still further the body temperature. If a stimulant is used for obtaining warmth (which can only be done if the patient is conscious), it should be given in the form of hot strong coffee or tea.

Even when recovery has apparently been effected, care must be taken to prevent exertion of the body, as every movement means more Oxygen required by the tissues, and although the blood may be carrying

sufficient Oxygen for the body while at rest, any movement of the muscles may cause a relapse into unconsciousness. Rest, therefore, is absolutely essential in cases of CO poisoning.

The procedure of treatment may be summarized as follows :—

First, remove the patient quickly into fresh air. In doing so, take great care to prevent chilling of the body surface, by providing that the patient is well wrapped up, and kept warm by warm blankets, hot-water bottles, etc.

Secondly, provide a copious supply of Oxygen, and by deep and slow rhythmic movements of the thoracic walls and respiratory muscles (Schaefer's method of artificial respiration), assist the lungs to take up an adequate supply of Oxygen, which will in course of time, slowly it may be, but surely, displace the CO from the hæmoglobin, and thus once more supply the tissues with Oxygen.

Absolute rest should then be given, and the patient kept lying on the back with the head low. The continued application of warmth will soon effect a restoration.

If these directions and precautions are carefully observed, a recovery will be effected in most cases of " gassing " in mines.

V

BREATHING APPARATUS

THE object of Mine Rescue Work is to save life and to recover and restore a mine in the disastrous event of an underground fire or explosion. Perhaps the greatest obstacle in the way of such work is the atmosphere of poisonous gases which fill the roadways of a mine after such a calamitous occurrence, and which quickly overpower and render unconscious men breathing it. Breathing Apparatus is designed to enable a man wearing it to penetrate into, and to exert himself actively in such a poisonous atmosphere for a period of at least one hour. According to Regulation 142 (Part IV, Regulations and Orders, 1913): "There shall be provided and maintained at every Mine suits of portable Breathing Apparatus. The Apparatus must be capable of enabling the wearer to remain for at least one hour in an irrespirable atmosphere," and Regulation 143 provides that: "There shall be kept and maintained in every Central Rescue Station not less than fifteen complete suits of Breathing Apparatus, with means of supplying Oxygen or Liquid Air to enable such Apparatus to be constantly used for two days, and of charging such Apparatus."

The New Regulations of 1920 provide further that:—

(*a*) No Breathing Apparatus shall be used except such as is approved by the Secretary of State.

(*b*) The supply of Oxygen to the wearer shall be not less than two litres per minute.

(*c*) The Oxygen must be analysed before use, and if found to contain more than 2 per cent. of impurities must not be used below ground or for practice above ground, where the person wearing the Apparatus is liable to be out of sight of the instructor. This does not refer to Liquid Air Apparatus.

(*d*) Every Breathing Apparatus, before being used, shall be tested for leakage in the prescribed manner.

The Mine Rescue Research Committee's First Report, page 31, gives as the best test for leakage : " To immerse the whole Apparatus in water with Oxygen turned on, and with the mouthpiece closed by the thumb. As the bags become distended bubbles rise from faulty joints on the circuit, while leakage of high pressure Oxygen becomes evident at once."

In their Second Report, 1920, they state : " We know of no test of leakage to equal that in which the Apparatus, tightly distended and with the Oxygen on, is plunged under water. The water test scrutinizes both the breathing circuit and the high-pressure joints ; it not only detects leakage, but also shows at once where it occurs.

" The fact that the test wets the Apparatus has been advanced as a serious disadvantage. A slight and transitory discomfort is barely worth mentioning when pitted against the safety of the wearer.

" No Rescue Apparatus should be used in a

poisonous atmosphere, unless it has passed a satisfactory leakage test."

For fifty years past many efforts have been made to produce a satisfactory portable Breathing Apparatus. The substantial progress which has been made latterly is largely due to the valuable assistance of physiologists like Dr. Haldane, who have shown the requirements of the human body which must be satisfied by a Breathing Apparatus under the trying conditions of Mine Rescue Work.

The supply of Oxygen must not fail, however strenuously a man may be exerting himself. The Carbon Dioxide exhaled must be regularly absorbed, and should never exceed 2 per cent. in the air breathed. There must be no obstruction to the free circulation of the air within the Apparatus. With respect to this important point of the resistance within the Apparatus, the Research Committee in their Second Report recommend that an Apparatus shall not be regarded as satisfactory unless the highest resistance of the Apparatus as a whole (measured immediately at the end of the two-hour period) does not exceed 3 inches of water when the rate of flow is 85 litres per minute.

The Apparatus should be absolutely air-tight so as to prevent the smallest leak inwards from the outside atmosphere.

Within the Apparatus there should be at the mouthpiece and tubes a small positive pressure. Too high a pressure within the Apparatus may be dangerous, as Dr. Haldane has pointed out: It is known from experiments with animals that with a positive pressure of as little as 2 inches of water, air begins to leak out from the lungs into the neighbouring cavities and tissues, and is said to gain access also to the blood in the form of small bubbles, and to be thus liable to cause air-embolism.

The temperature should be kept low, and should never exceed 20° C. (36° Fahr.) above the outside temperature, assuming this to be normal.

The Apparatus should be as simple and as "fool-proof" as possible. It should be of light weight, and adapted to be worn comfortably by men doing hard work in a confined space.

A man wearing Breathing Apparatus in a poisonous atmosphere underground may find his Oxygen supply or his purifier failing, when he is some distance from fresh air. His natural inclination will be to hurry out at his utmost speed, but this must be resisted as a fatal proceeding.

It is useful to know that the most economical speed, with the object of conserving the Oxygen supply and the purifier as long as possible, is judged by the Research Committee (Second Report) to be 2½ miles an hour when travelling a flat road in a mine.

The Aerophor.

Since Sir James Dewar succeeded in liquefying atmospheric air in the year 1891, the evaporation of liquid air has become the principal means of obtaining Oxygen.

The following table shows the volume of gas obtainable from 1 litre of liquid air of varying Oxygen content :—

Per Cent. of Oxygen.	Volume of Liquid.		Mass of Liquid.		Volume of Gas at Atmospheric Pressure.			
					At 0° C.		At 20° C.	
	Litre.	C. Ft.	Lb.	Kilos.	Litres.	C. Ft.	Litres.	C. Ft.
Pure Oxygen	1	0·0353	2·49	1·13	791	27·9	849	30·0
50 per cent..	1	0·0353	2·16	0·98	725	25·6	778	27·5
21 per cent..	1	0·0353	1·89	0·86	665	23·5	714	25·2

It will be observed that the liquid turning into a gaseous state expands about 800 times its volume.

10 lb. weight of liquid air are equivalent to 3,540 litres of breathable air containing about 2,500 litres of Oxygen.

The temperature of liquefaction is :—

For 21·6 per cent. Oxygen in Liquid — 194° C.
For 59·5 per cent. Oxygen in Liquid — 190° C.
For 100 per cent. Oxygen in Liquid — 182° C.

These facts indicate the value of liquid air for use in portable Self-contained Breathing Apparatus.

The first Liquid Air Apparatus, however, which was known as the " Aerolith," and which is described in the First Report of the Royal Commission of Mines, 1907, was not a success. Since then many improvements have been made, and the modern Aerophor is a highly efficient Breathing Apparatus.

The improvement of the Aerophor has been due mainly to the efforts of Colonel W. C. Blackett, the Chairman of the Coal Owners Committee, which controls the Durham and Northumberland Collieries Fire and Rescue Brigade.

In its main features of a " Pack " so constructed that the liquid air absorbed in it can be boiled off in sufficient quantities under the action of the atmosphere surrounding the Pack, and of the sleeveless jacket, the Aerophor is the invention of Colonel Blackett, for which he took out a patent in 1911.

Since then various improvements have been made in it with his assistance and advice.

Fig. 4 shows the latest pattern of 1919.

A is a case or canister, generally called the " pack," made of cupro-nickel, shaped like a knapsack to fit the back, and capable of holding 7 lb. of liquid air. One lb. of the liquid gives a supply of air

sufficient normally for a period of twenty minutes. The inside of the canister is filled with asbestos wool, about 17 oz. of it (free from all carbonaceous matter), which absorbs the liquid air, and prevents it running out, even when the canister is turned upside down. There are two openings in the top of the case, S and S_1. Through S the liquid air is poured in, and is quickly distributed through the

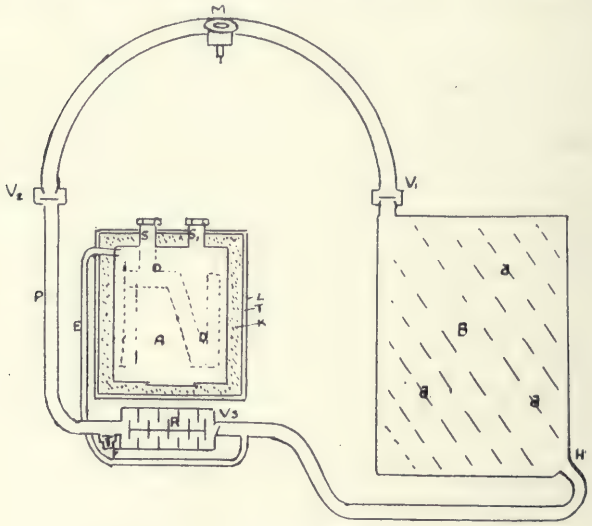


FIG. 4.—THE AEROPHOR.

wool by the perforated tube D, which is connected with the opening S. The other opening, S_1, is to allow of the outlet of the air in the pack, which is displaced by the liquid air being poured in.

The pack is insulated from the outside temperature by a layer, half-an-inch thick, of magnesium asbestos, K, which is cast in two parts, so that it can be removed or fixed into position conveniently. Over the magnesium asbestos is a layer of felt, T, $\frac{1}{4}$ inch thick,

and over that again a cover of leather, L. This insulation permits the penetration of sufficient heat to volatilize the liquid air at the required rate. The difference in temperature between the outer atmosphere and inside the canister is usually about 400° Fahr. At the start the rate of evaporation is about 25 litres per minute, and gradually falls till at the end of two hours it is about 9 litres per minute.

But the proportion of Oxygen present in the air is increasing all the time, being usually 60 per cent. at the beginning and 90 per cent. during the latter stages of evaporation. This is so, because the Nitrogen in the liquid air evaporates faster than the Oxygen. Nitrogen having a lower temperature of liquefaction than Oxygen, allows the Oxygen to liquefy more rapidly than the Nitrogen. The converse applies to the changing from liquid to gaseous state. The Nitrogen evaporates slightly faster than the Oxygen, so that the air product becomes richer in Oxygen during the time of wearing the Apparatus.

At the bottom of the canister is a cover, which is easily removable to allow of examination or repairs.

The *breathing bag*, B, is made of rubber. It is carried in a canvas bag for protection, and is worn on the front of the body. The diagonal ribs, *d*, prevent the entire collapse or flattening of this bag. The air enters the bag at the bottom corner, H, and passes diagonally with the ribs or studs up to the opposite top corner, where a connection is fitted to receive the valve V_1, through which it passes to the mouthpiece.

The *purifier*, R, is carried under the pack on the wearer's back. It is a box about 4 inches square and 8 inches long, divided into two parallel passages, each carrying nine baffle plates, by means of which

the air is brought into close proximity with the granulated caustic soda, which is placed in perforated pockets between the baffle plates. The air from the pack passes through the pipe E, a copper pipe, $\frac{3}{8}$-inch inside diameter, to the breathing bag, and thence through the valve V_1 to the mouthpiece M.

This mouthpiece carries the nose-clip fixed to it so that it cannot be pulled off. The exhaled air passes through the valve V_2 into the pipe P, which brings it past the automatic relief valve F to the purifier.

This valve F is set to blow off at a pressure of about $2\frac{1}{2}$ inches water gauge.

At V_3, in front of the purifier, is a non-return valve, which prevents the pure air from the pack short-circuiting through the purifier to the relief valve F, and thus chilling the caustic and reducing its power of absorbing Carbonic Acid gas.

The volume of air passing out of the tube E may be more than enough at times to supply the wearer's requirements, but in case of special need this is supplemented by the air from the purifier, which acts as a reserve.

The circulation pipes are all 1 inch in diameter, an ample size, with a view to minimizing the frictional resistance to the passage of the air through the Apparatus.

In circulating, the cold air is warmed a little, so that when it arrives at the mouthpiece it is of a pleasantly cool temperature for breathing.

The whole Apparatus is carried on a strong canvas jacket, which is strapped to the wearer's body. The weight of the pack, which is carried on the back, is taken by straps passing over the shoulders and across the chest to the lower opposite side of the pack.

On the back of the jacket is a thick pad of felt to protect the wearer's body from the cold coming from the liquid air in the pack.

In comparison with other Breathing Apparatus a special advantage of the "Aerophor" is that it provides a more ample supply of Oxygen, and at a pleasantly cool temperature; and it much reduces the danger of a serious rise in the body temperature of the wearer. It weighs when empty 30 lb. 8 oz., or 37 lb. when charged with 6½ lb. of liquid air. These figures will be greatly reduced yet.

The Proto.

The Proto, or Fleuss, is the oldest Breathing Apparatus, and also one which is in most extensive use in the United Kingdom at the present time. According to the First Report of the Mine Rescue Research Committee, 1918, there were in use at British Rescue Stations and mines in 1916, 913 Proto, 455 Meco, 22 Draeger, 132 Weg, and 96 Aerophor.

The inception of the Proto Apparatus is due to Mr. Henry A. Fleuss, whose first patents are dated 1879. When serving at sea as an officer in the Merchant Service, he designed a Self-contained Diving Apparatus, which he adapted afterwards for use in mines.

It was used tentatively in 1881 at Seaham Colliery, co. Durham, after a big explosion there, and soon afterwards at Killingworth Colliery, Northumberland, when the downcast shaft had collapsed, and some men had to be brought out by a furnace upcast shaft. But perhaps the chief value of these early trials of it was to show the difficulties that had to be met, and the necessity of men being carefully trained beforehand in the use of such Apparatus.

Great credit is due to Mr. Fleuss for his persevering efforts, and his many personal experiments at

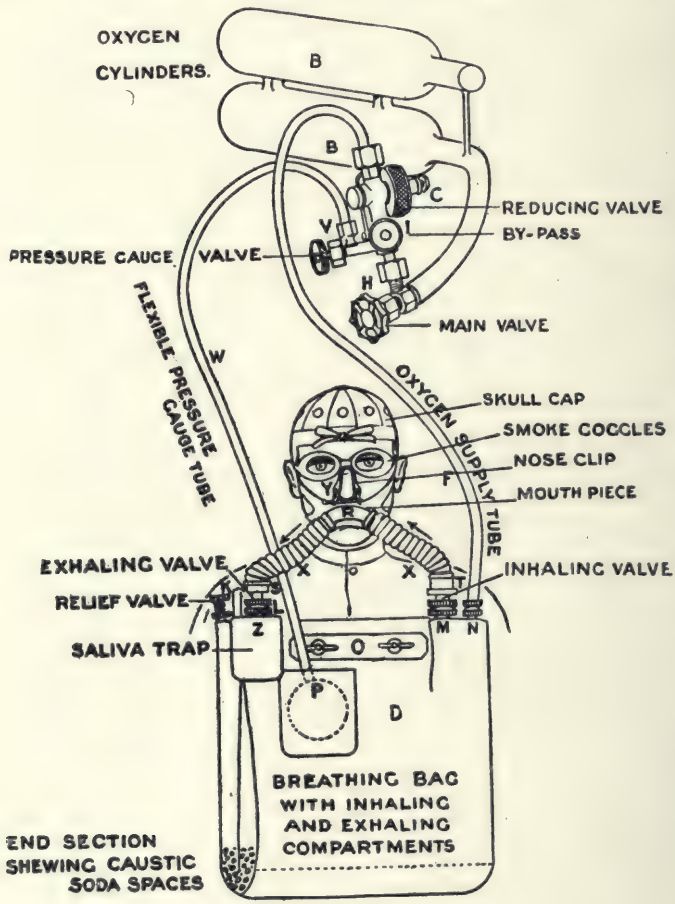


FIG. 5.—DIAGRAM OF PROTO APPARATUS.

considerable risk to himself at a time when little was known about these breathing appliances.

In its modern form, as made by Messrs. Siebe Gorman and Co., Ltd., London, the Proto is described in the First Report (1918) of the Mine Rescue Apparatus Research Committee as follows (see Fig. 5): "The cylinders B, together hold 280 litres of Oxygen under a pressure of 120 atmospheres. The reducing valve C, when correctly adjusted, allows a constant flow of Oxygen of 2 litres (122 c. in.) a minute to pass into the breathing circuit. The makers also supply reducing valves which can be set by the wearer to give discharges ranging between 0·6 and 3 litres per minute. The Oxygen passes through a flexible tube, F, running over the wearer's left shoulder, and enters the bag at N, where it joins the air being drawn into the lungs. Light mica valves are fitted into the tubes at M and L to control the direction of flow of the air. The breathing bag, which is of rubber, is divided into two compartments by a partition reaching nearly to the bottom, and in the bottom of the bag is placed a charge of caustic soda weighing 3 to 5 lb. Either stick soda is employed, or coke nuts coated with caustic. The air, in travelling from one compartment to the other, has thus to find its way through the soda, and, in doing so, the CO_2 is absorbed. By shaking the bag from time to time new surfaces of the absorbent are exposed to the air, and the absorption of CO_2 is facilitated. A saliva trap, Z, is fitted under the exhaling tube. The pressure gauge, which is carried in a pocket in front of the bag, is connected to the Oxygen supply by means of a highly flexible metal tube, W. The wearer can thus read his own gauge. A relief valve, operated by the wearer, is placed on the bag at K. Fig. 6 shows how by means of a strong steel neck the main valve wheel H is brought to the front within reach of the wearer.

FIG. 6.—FRONT VIEW OF PROTO ON WEARER.

The by-pass tube I (Fig. 5) short-circuits the reducing valve C. Oxygen can be discharged through the by-pass by opening the cock I. V is the pressure

gauge valve. It is only opened when the gauge is to be read."

The Proto Apparatus has proved its value in practical use after explosions on several occasions. The most recent instance, that has been placed on record, was after the explosion at Podmore Hall Colliery, Staffs.

In his Report on this explosion (July 1920), the Chief Inspector of Mines writes that four brigades wearing Proto Apparatus were engaged for more than twelve months. Thirty-four stoppings were built in an atmosphere devoid of Oxygen, and the seam was opened up, step by step, until finally the last body was brought out on August 19, 1919. " The test to which the Apparatus (Proto) and the brigades were put is probably the greatest ever applied to Rescue Brigades wearing Self-contained Breathing Apparatus, and its successful completion reflects the greatest credit on all concerned."

The following rules for putting on and testing the Proto Apparatus have been found useful in practice :—

Rules for Proto Apparatus.

Before Putting on Dress.

(1) The Dress must not be worn by any person unwell, or in any way indisposed.
(2) Artificial teeth, if likely to be dangerous, should be removed.
(3) It is advisable not to take too heavy a meal before wearing the dress, and to abstain strictly from alcoholic liquors.
(4) Turn on main valve and note that the by-pass is shut.
(5) Examine pressure gauge, which should read not less than 120 atmospheres.
(6) Tighten all joints.
(7) Test with a smouldering lamp-wick for leakage round

the main valve, reducer, by-pass valve, pressure gauge valve, also each end of the Oxygen supply tube and pressure gauge tube.

(8) Examine carefully all valves.

(9) Turn off main valve.

PUTTING ON AND TESTING APPARATUS.

(1) Put Apparatus on over left shoulder.

(2) Buckle up body belts and adjust balance of Apparatus on the shoulders.

(3) Test for leakages out of bag, tubes, etc., as follows :—

(*a*) Hold the inhaling tube tightly ; blow into the bag until it is three parts full ; press the bag evenly and listen for any escape, and note whether the bag deflates.

(*b*) Suck all air out of bag, forming a partial vacuum therein, place the tongue in the orifice of the mouthpiece which will stick to the tongue if the bag is tight. Pay particular attention to the mouthpiece and inhaling tube, by listening carefully for leakages.

(4) Turn on main valve two full turns, and fix locking arrangement.

(5) Put on nose-clip.

(6) Put tongue in orifice of mouthpiece and flush out bag with Oxygen.

(7) Exhale into atmosphere, and take next inhalation from bag.

(8) Strap on mouthpiece.

(9) Examine all joints and inspect Apparatus carefully. This to be done by the Captain. Each man then to go over his own dress himself.

(10) Immerse Apparatus in fumes (Formaldehyde) and test for leakages.

(11) Read gauge.

(12) Do not forget lamps, salvators, and birds.

The Tissot Apparatus.

This Apparatus was first introduced in 1907, and has been extensively used in France for Mine Rescue Work and Army purposes. It is carried on

the back, and the wearer bears no part of it in front to hamper his movements. The pressure gauges

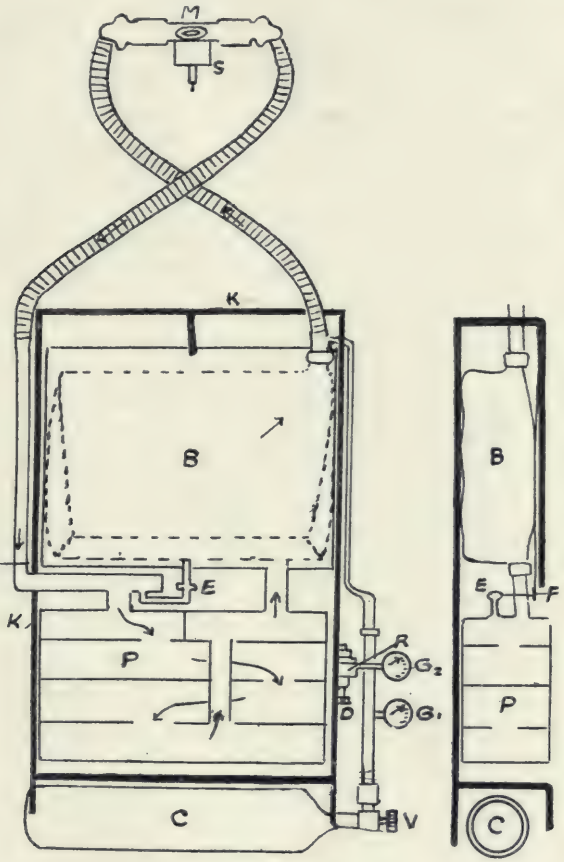


FIG. 7.—TISSOT APPARATUS.

G_1 and G_2 (see Fig. 7) are so placed that the wearer can see them easily.

A unique feature in comparison with other Breathing Apparatus is the use of a *solution* of caustic

potash to purify the exhaled air instead of the usual solid alkali.

During transport the purifier is empty. Small boxes, each containing sufficient caustic potash for one charge, are carried.

This is dissolved in 1·05 litres of water, and when cool the solution is poured into the purifier immediately before use.

The advantage is that less heat is produced than when solid alkali is used.

On the other hand, it is troublesome to prepare, and there is the risk that when the wearer is crawling along the fallen passages of a mine the solution may get into the breathing tubes.

The Oxygen is carried in a single cylinder, C, the outlet of which is controlled by a valve, V, within easy reach of the wearer's right hand. The gauge G_1 registers the pressure of the Oxygen, and indicates when the supply is getting low.

R is a reducing valve, which is manipulated by the wearer through the adjusting screw D. The gauge G_2 registers the discharge of the Oxygen from the reducing valve. On the face of the gauge are four points marked respectively: "Rest," "Marching," "Work," and "Aid." In accordance with what he is doing, the wearer adjusts the screw D to the supply of Oxygen which he requires, as recorded by the pointer on the gauge.

The supply indicated by the fourth mark, "Aid," is only needed in case of emergency, when the breathing bag is flat, or when assistance is required for a second man whose supply of Oxygen has failed. "Work" denotes strenuous exertion, such as climbing up a road of steep gradient.

Another notable feature is the control of the relief valve E by the expanding and contracting

movements of the breathing bag B. A light wooden flap, F, is attached to the bag by a hinge at its upper end. E is a sliding valve with an attachment to F, so that as the bag is inflated the slide is moved and uncovers an opening allowing the discharge of gas.

The inhalation and exhalation valves V_1 and V_2 are hinged clacks of brass placed within a metallic extension of the mouthpiece M.

Beneath the mouthpiece is a saliva trap, S, which can be emptied by means of the small chain L.

The Gibbs Apparatus.

In 1914 the United States Bureau of Mines [1] commissioned Mr. William E. Gibbs, a mechanical engineer of New York, to investigate the problem, and to construct an efficient Breathing Apparatus for Mine Rescue Work.

In 1917 Mr. Gibbs produced an Apparatus, which, after careful testing, has been officially approved by the U.S.A. Bureau of Mines.

Its special feature is the way in which the rate of supply of Oxygen to the wearer is regulated by his breathing.

The rate of supply is variable from about half a litre a minute, which is all a man needs when at rest, to two or three litres, which he requires when exerting himself vigorously.

Sir William E. Garforth was the first to adopt

[1] The U.S.A. Bureau of Mines, by its useful investigations and valuable work, has made itself known and appreciated throughout the coal-mining world. It was established by Act of Congress in May 1910. Its purpose, as outlined in the Organic Act, has been stated by an American engineer to be twofold.

(1) "To promote conditions leading to the improvement of the safety and health of the miner."

(2) "The efficient and economic development of our mining, metallurgical, and other mining industries."

this method of control of the Oxygen supply by the lungs of the wearer, in his WEG Apparatus. In the Proto and some other designs the supply of Oxygen is set at a fixed quantity per minute.

The crucial point is the reducing valve. In the Gibbs Apparatus this is of excellent design, and extremely sensitive to variations of pressure. It reduces the pressure of the Oxygen passing through it from 2,000 lb. to $2\frac{1}{2}$ lb. per square inch.

The action of this reducing valve in conjunction with the inlet valve, I, into the breathing bag is described by the makers as follows :—

> The reducing valve admits Oxygen from the bottle (cylinder), reducing it to a pressure that may be controlled by the admission valve. When the admission valve is closed, Oxygen is held in the reducing valve under pressure, which stretches the flexible metallic bellows and pulls on a toggle to close off the port where Oxygen enters, at the same time opening the port where Oxygen discharges from the reducing valve into the admission valve.
>
> The discharge from the reducing valve is dependent upon the deflation of the breathing bag to operate the admission valve.
>
> In practice, no matter how great the exertion, every demand of the wearer for Oxygen is met; and if the wearer is at rest the Oxygen supply is conserved to his minimum requirements.

The breathing bag is of the bellows type (see Fig. 8). The supply of Oxygen in it is maintained by the movement of the weighted flap or lever, which controls the Oxygen admission valve. As the bag empties, the lever falls. When the bag is three-quarters emptied the lever comes into contact with and opens the valve, admitting a fresh supply of Oxygen. The bag expands till the weighted lever is lifted off the valve, which then closes.

On leaving the reducing valve, the Oxygen

passes a safety valve, which is set to blow off at a pressure of half an atmosphere. When discharging it sounds a whistle, and thus gives warning of leakage at the reducing valve.

The wearer's lungs are the motive power which keeps the air circulating through the Apparatus.

The purifier, or absorbing can, is designed to reduce the excessive heating which arises from the chemical reaction of Carbonic Acid gas with an alkali. Sheets of fine wire gauze are dipped in molten caustic soda containing about 20 per cent. of water (or one molecule of water (H_2O) to two of caustic soda (NaHO)). The caustic soda solidifies on the gauze when cold, forming reinforced plates about $\frac{1}{16}$ inch thick, between which the expired air passes.

The avidity of the soda for moisture is thus partly satisfied, and the heat produced is considerably less than in some other forms of Apparatus, and the purifier is effective at a much lower temperature. Some twenty of these gauze sheets coated with the soda are placed vertically and parallel to each other, at $\frac{1}{5}$th inch apart, and the exhaled air is coursed between them. This arrangement allows the condensed moisture and the sodium carbonate in solution to drain away readily.

The air from the purifier passes into a cooler, made of blackened copper, where some of the heat is lost by radiation.

A single cylinder contains the Oxygen at a pressure of 135 atmospheres.

A stop valve controls the outlet from the cylinder, and a gauge indicates the pressure of the gas. This gauge is not visible, but it is read by touch, and an alarm is sounded when the pressure of the gas in the cylinder falls to 30 atmospheres.

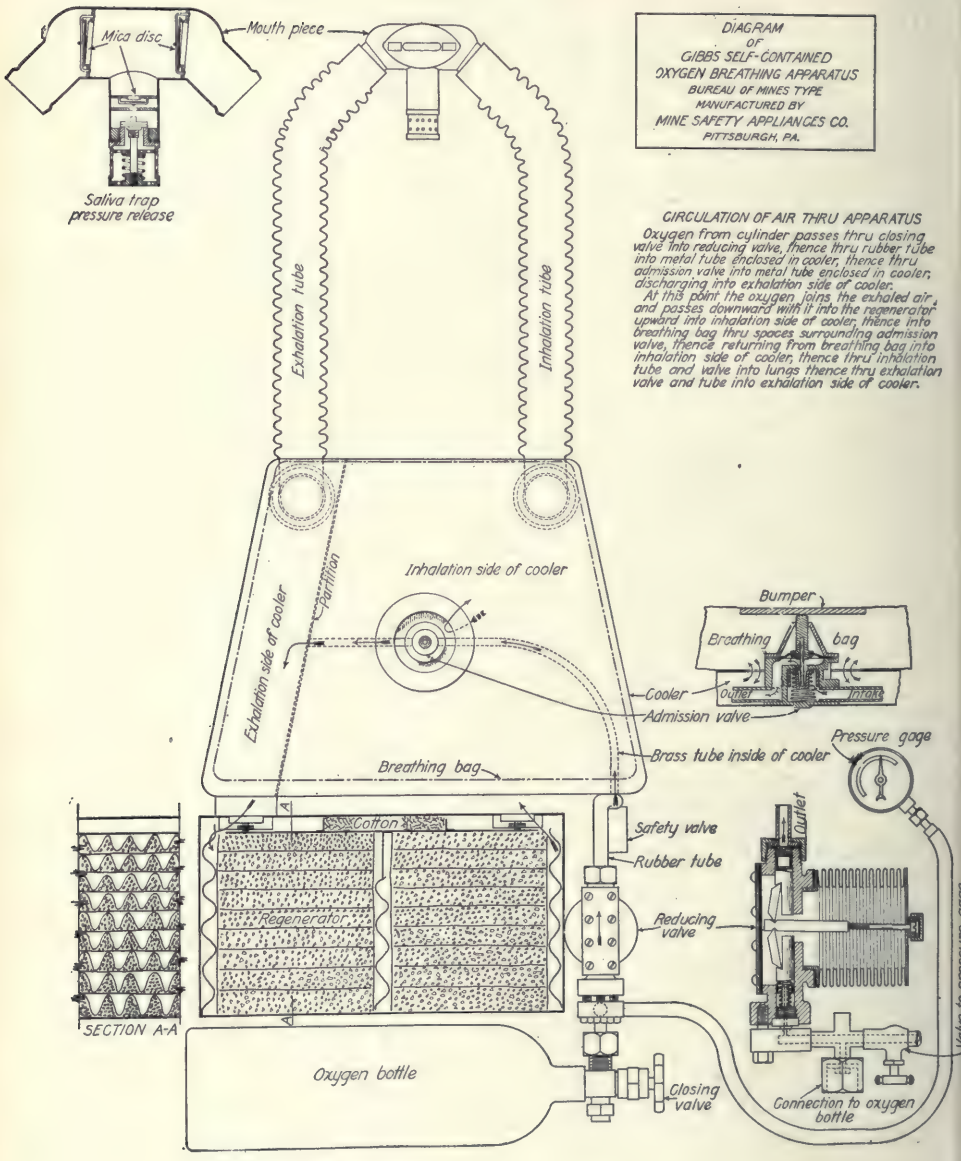

Mica disc
Mouth piece
Saliva trap
pressure release
DIAGRAM
OF
GIBBS SELF-CONTAINED
OXYGEN BREATHING APPARATUS
BUREAU OF MINES TYPE
MANUFACTURED BY
MINE SAFETY APPLIANCES CO.
PITTSBURGH, PA.
CIRCULATION OF AIR THRU APPARATUS
Oxygen from cylinder passes thru closing valve into reducing valve, thence thru rubber tube into metal tube enclosed in cooler, thence thru admission valve into metal tube enclosed in cooler, discharging into exhalation side of cooler.
At this point the oxygen joins the exhaled air and passes downward with it into the regenerator upward into inhalation side of cooler, thence into breathing bag thru spaces surrounding admission valve, thence returning from breathing bag into inhalation side of cooler, thence thru inhalation tube and valve into lungs thence thru exhalation valve and tube into exhalation side of cooler.
Exhalation tube
Inhalation tube
Partition
Inhalation side of cooler
Exhalation side of cooler
Bumper
Breathing bag
Cooler
Outlet
Intake
Admission valve
Pressure gage
Brass tube inside of cooler
Breathing bag
Cotton
Safety valve
Rubber tube
Outlet
Regenerator
Reducing valve
Valve to pressure gage
SECTION A-A
Oxygen bottle
Closing valve
Connection to oxygen bottle
BACK VIEW

FIG. 8.—FLOW DIAGRAM OF GIBBS APPARATUS.

The Apparatus is covered with a protecting case of aluminium, is mounted on a frame of steel tubing, and is carried on the back.

In this respect, and in its general appearance and compactness, it resembles the Tissot Apparatus.

Its weight compares favourably with other types.

The Paul.

The most recent American Self-contained Breathing Apparatus is the "Paul," which was formally approved by the U.S.A. Bureau of Mines on January 15, 1920.

Competitive tests in U.S.A. have shown it to possess advantages in comparison with the Proto and the Gibbs Apparatuses.

It is made by the American Atmos. Corporation (formerly the Draeger Oxygen Apparatus Co.), of Pittsburgh, Pa.

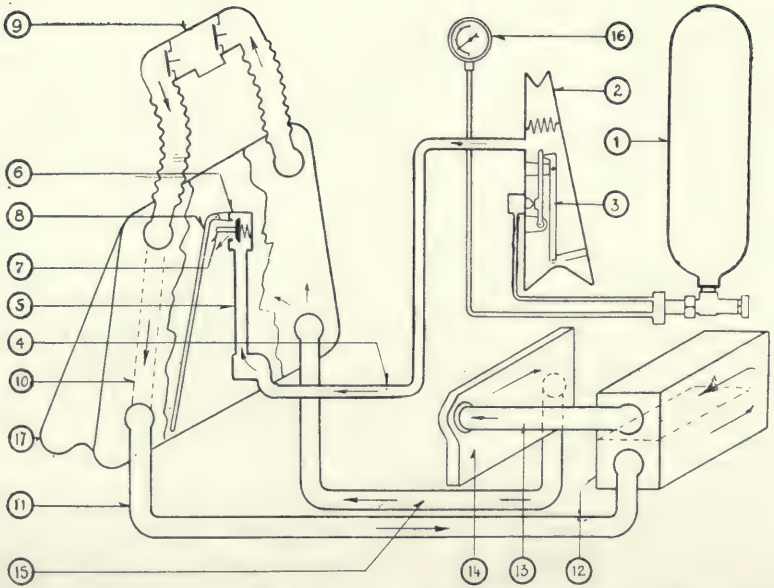
The inventor, Mr. James W. Paul, is a mining engineer, who has had a wide and lengthy experience in practical Rescue Work. For seven years—1908 to 1915—he was in charge of the Mine Rescue Work of the U.S.A. Bureau of Mines.

The special feature in the construction of his Apparatus is the device by which the supply of Oxygen is adjusted to the requirements of the wearer, and a small positive pressure is maintained within the Apparatus under very varying conditions of work.

The Oxygen at high pressure passes from the cylinder (1) (see Fig. 9) to the bellows (2), through the valve (3), and thence to the valve (6), which is inside the breathing bag (17).

The valve (6) is opened by the lever (8), which is attached to the front wall of the bag.

When the bag is deflated, this lever comes into contact with the valve and opens it. Oxygen flows



The Paul
American Atmos Corporation

1	Oxygen Cylinder
2	Bellows
3	Self-adjusting Oxygen Feed Valve
4	Flexible Oxygen Feed Tube
5	Oxygen Feed Tube (in bag)
6	Oxygen Feed Valve
7	Valve Stem
8	Lever (attached to front Wall of Bag)
9	Respiration Chamber
10	Exhalation Tube (in Bag)
11	Flexible Exhalation Tube
12	Air Regenerator
13	Regenerator to Cooler Tube
14	Cooler
15	Flexible Inhalation Tube
16	Pressure Gauge
17	Breathing Bag

FIG. 9.—PAUL BREATHING APPARATUS. FLOW DIAGRAM.

in until the bag is filled about two-thirds full, when the valve closes.

No Oxygen passes through the valve (3) into the bellows when the valve (6) is closed.

The bag is always more than one-third full.

The pressure at valve (3), and through the feed tube right up to the valve (6), is maintained at 6 ounces per square inch.

During practical tests under varying conditions of work the pressure inside the Apparatus has been always a little higher than the pressure outside.

This positive pressure inside is a most valuable condition in Mine Rescue Work, where the outside atmosphere usually contains Carbon Monoxide ready to enter through any leak in the Apparatus if there is a suction inwards. But, as pointed out by the Research Committee (Second Report), when the holes are large or numerous, there is no way of maintaining a continuous positive pressure in any Breathing Apparatus.

The Oxygen goes straight from the cylinder to the breathing bag without any admixture of exhaled air.

The exhaled air passes directly through the regenerator or purifier (12), and thence through the cooler (14) to the breathing bag.

Three and a half lb. of "flake" caustic soda is used in the regenerator. In this form the soda appears to be more effective than in the "stick" or "granulated" forms.

The Headgear deserves notice. A leather cap with a metal guard at the top protects the head. A leather skirt, extending downwards from the cap behind, covers the neck and protects it from fire and water. The nose-clip and the mouthpiece are designed with a view to the comfort of the wearer,

and the attached flexible rubber pipes enable him to move his head freely.

A series of competitive tests were carried out during a couple days in July 1919 by Mr. Duncan McDonald, Inspector of Mines and General Superintendent of Mine Rescue Work at Alberta, at Calgary, Canada, with the Paul, and the Gibbs, and the Proto Apparatuses.

Three men were selected, from thirty to thirty-three years of age, in good physical condition.

They wore each type of apparatus in turn during the trials, so that the results cannot be attributed to the individual strength or efficiency of the wearer.

The work they were called upon to do in the various tests was " equal to and more than would be asked of any man to perform after any serious accident."

In his report Mr. MacDonald sums up the results as follows :—

During the test made on July 2nd, in which there was no strenuous work performed, all three different types of Self-contained Breathing Apparatus were on an equal basis, as there were no bad effects to any of the wearers during the period of this test, and each wearer was satisfied with the results. But during the tests on July 3rd the Proto and the Gibbs Apparatuses were equal to the Paul during the first hour's work on this test. After this period the Proto gave continuous worry to the wearer owing to the high temperature, and the excessive accumulation of saliva, which reduced the efficiency of the wearer down to the lowest ebb, he having to use the by-pass at regular intervals ; also it showed he was concentrating all his thoughts on the high temperature of the soda in the breathing bag. With a man under these conditions there is a grave possibility of his making serious errors. He also reduced the supply of Oxygen very rapidly by the excessive use of the by-pass ; had a bad effect on the throat owing to the high temperature of the inhalation ; also showed an

element of negative pressure which is a dangerous element with any type of Self-contained Breathing Apparatus.

The Gibbs Apparatus, after the period of one hour's work, seemed to give the wearer considerable inconvenience, as well as considerable effort when inhaling. He seemed to wish for an increased supply of Oxygen when he was digging clay and throwing it into the stopping which was above his level. There is also considerable inconvenience to the wearer when having to pass through small openings, as shown in part of this test; also the bad effects on the wearer as shown when in use for a period as given in this test.

There is always the possibility of the admission valve, which is attached to the breathing bag, not acting, causing a continuous flow of Oxygen to the wearer, passing from the cylinder and through the automatic reducing valve to the breathing bag, causing an excessive back pressure to the wearer, making it necessary for him to detach his mouthpiece and nose-clip, which is a serious practice to the wearer if he happens to be in a poisonous mixture of air.

This has occurred on various occasions during the use of the Gibbs Apparatus, showing that there is a serious defect with the admission valve attached to this Apparatus, which is the most vital part of this equipment, as the wearer's life depends on this part when in use. The dead breathing space on this Apparatus must have a distinct effect on the wearer during an excessive test as given, also the danger of the excessive negative pressure as found during the tests, which is an extremely dangerous feature of this Apparatus.

The Paul Apparatus proved to be an efficient Apparatus during the complete period of these two days' tests. The circulating system on this Apparatus is well arranged, the Oxygen passing direct from the cylinder to the automatic refiller, and then to the breathing bag without passing through the regenerator, which increased the efficiency of the wearer 75 per cent. during the period of work or tests to be completed. The position of the breathing valves cut down the dead breathing space to zero; also, the noticeable action of the automatic refiller gives excessive confidence to the wearer at all times, the wearer having no effort to make in breathing, and the results showed that in any kind of strenuous work to be completed there was at all times passing to the wearer a plentiful supply of Oxygen, which did not at any time during the tests show any higher than 5 degrees higher than the

outside temperature, which must have an effective bearing on the wearer. The low velocity of the exhaled air passing through the regenerator, and also flake soda being used, there is almost a complete absorption of the CO_2, and also the extensive cooling system attached to this Apparatus has a very important bearing on this type of Apparatus; also having attached to it a by-pass, which is very essential for any type of Apparatus, either used by a reducing valve, or

FIG. 10.—PAUL APPARATUS. GENERAL VIEW.

by an automatic arrangement, and the Apparatus showing in all the tests made positive pressure and good guarantee of the safety of this Apparatus.

The men wearing the Apparatus during the two days' tests were more than satisfied, being in good condition at the finish of each of the tests and having no ill effects.

Further competitive tests made in August 1919

at Beekman, Washington, U.S.A., under the superintendence of Mr. William A. Shaw, the General Superintendent of the Roslyn Fuel Company, bring out also the advantages of the Paul Apparatus.

In supply of Oxygen according to needs of wearer, effective removal of Carbon Dioxide, maintenance of positive pressure, low temperature, and freedom of movement to the wearer, it is satisfactory to note that marked advance has been achieved by the Paul Apparatus. Fig. 10 is a general view of it.

Briggs' Apparatus.

The most recent Self-contained Compressed Oxygen Breathing Apparatus is that designed by Dr. Briggs, and fully described in the Second Report of the Research Committee (July 1920).

This description is its first introduction to public notice. It is evident from the description that every detail of its construction has been carefully considered. With accumulating experience in the hands of capable experts the last apparatus should be the best.

It may be noted here with respect to the Oxygen feed, that the method of a set supply of two litres per minute, increased when desired by means of a by-pass, has been adopted. This method has been preferred to the self-regulating feed of the Gibbs and the Paul Apparatuses, because in the event of the Oxygen being impure, a not unusual event in English experience, there is a danger in the latter apparatuses of an accumulation of Nitrogen in the breathing bag preventing its deflation, and thus preventing the Oxygen feed functioning; and also because the mechanism of the self-regulating feeds is more complicated, more likely to get out of order, than the constant delivery valve.

A great deal of attention has been given to the design and construction of the purifier in the Briggs' Apparatus, and tests which are recorded in the Second Report of the Rescue Committee show that it is highly efficient in absorbing the Carbon Dioxide.

It is worth noting that amongst men of practical experience there is a difference of opinion about fixing the supply of oxygen at a minimum of two litres per minute. Mr. Walter Clifford, chief instructor at the North Staffordshire Rescue Station, has stated that the "operations at all the disasters in North Staffordshire were carried out with the reducing valve (Proto apparatus) set at 1·75 litres per minute up to the time of the Minnie Pit explosion in 1918. The majority of rescue men would be pleased to have the flow cut down to that figure again, During the long recovery operations following the explosion at Norton Colliery, Stoke-on-Trent, about half the men engaged asked to be allowed to wear apparatus which was giving only 1·5 litres per minute."

"Two litres being frequently more than enough the result is that for the greater part of the time the wearer is uncomfortable through his breathing bag being distended, and he has constantly to stop working to press his relief valve, to allow the accumulated oxygen to escape and be wasted."

VI

MISCELLANEOUS APPARATUS.

BESIDES portable Self-contained Breathing Apparatus, a large number of other appliances are required at Rescue Stations. Some mention will now be made of them.

Smoke Helmets.

These are of great service where the distance of irrespirable atmosphere to be traversed is not more than 60 or 70 yards from good air.

This occurs not infrequently with underground fires. Where connection can be made with a compressed air main there is an additional advantage in the air being cold.

In comparison with Self-contained Breathing Apparatus, the Smoke Helmet is much simpler, less hampering to the movements of the wearer, gives him a more ample supply of good cool air, and protects his head from injury.

There have been occasions in actual Rescue Work where Self-contained Breathing Apparatus has been discarded in favour of Smoke Helmets. An instance occurred at Cadeby Colliery, Yorkshire, after the explosion there, in 1912.

In dealing with some underground fires, where the temperature was high, men wearing Breathing Apparatus found it impossible to work. With Smoke Helmets, however, they were able to do what was required.

By means of a pump or bellows, or blower fan, the ordinary atmospheric air is delivered to the helmet through lengths of armoured hose, 1 inch diameter

FIG. 11.—ELSWICK SMOKE HELMET AND BELLOWS.

inside (see Fig. 11). To avoid risk of damage, this armoured hose is made so strong that a horse and cart can pass over it without squeezing it. Travelling in dense smoke, a man wearing a Smoke Helmet

has the hose as a tail behind him, by which he can guide himself out through the densest atmosphere. Dr. Haldane found that a man needs about 6 cubic feet of fresh air per minute to support respiration and to keep him cool when working in a Smoke Helmet. The Buffalo Blower, made by Buffalo Ltd., U.S.A., is one of the best appliances for forcing air through the hose. A test of it, when connected with an air metre, through different lengths of 1 inch tubing, gave the following results :—

Through 60 feet of tubing, when driven at the rate of sixty revolutions a minute of the handle, it gave 5·50 cubic feet of air per minute ; through 120 feet of tubing, 4·71 cubic feet of air ; and when the length of tubing was 180 feet the delivery of air was 4·12 cubic feet.

A bellows tested under the same conditions, and driven at sixty strokes per minute, gave 7·98 cubic feet, 6·66 cubic feet, and 6·54 cubic feet of air through the different lengths of hose as above. But the exertion required to drive the bellows was very much greater than to drive the blower. The tubing was coiled so that it offered its maximum resistance to the passage of the air. It is much easier to keep the blower going for any length of time.

These helmets are made of raw hide, and are fitted with strong clear mica windows in aluminium hinged frames. A small brush, carried in a pocket opening into the helmet, enables the wearer to clean the windows and clear them of moisture which condenses on them. Some types contain an exhaust valve for the escape of excess air, and of the vitiated exhaled air ; and in others it passes down and out under a morocco leather apron, stretching from the helmet under the coat and vest of the wearer. This latter arrangement tends to cool the body.

Many patterns are fitted with telephones or speaking apparatus, enabling the wearer to communicate with the man at the blower. This creates confidence, and allows the supply of air to be varied according to needs. The wire connecting the transmitter and receiver of the telephone is carried inside the flexible hose. 1,293 Smoke Helmets were in use at mines in the United Kingdom in 1918 (see Report of Chief Inspector of Mines).

The drawbacks of the Smoke Helmet are pointed out in the Second Report of the Research Committee. A heavy fall of stone may flatten or hold the hose and so trap the man in the helmet. The hose is unwieldy and troublesome for a man to drag behind him. The Committee consider that under the conditions usually obtained in a mine, its range is limited to about 50 yards from fresh air. It limits the sight and hearing of the wearer, and each helmet requires the attention of two men.

The Antipoys Apparatus.

The Antipoys Apparatus is a yet simpler appliance for enabling the wearer to work in a poisonous atmosphere at shorter distances of 20 or 30 feet from fresh air.

In its simplest form it consists of an ordinary rubber mouthpiece, making an airtight joint with the mouth, to which is fitted a T piece carrying an inlet and an outlet valve. To the inlet end is attached a long tube of smooth bore leading to the fresh air.

The air is drawn through this tube by the lungs, and breathed out into the atmosphere through the outlet (non-return) valve.

Evidently this Apparatus can only be used at distances where the friction of the air drawn through the tube is not too great for the powers of the lungs.

The lungs act in an intermittent fashion, suction alternating with rest. This intermittent action much lessens their ability to induce a steady flow of air along a tube.

" If the plain mouthpiece and hose appliance is going to be of practical use, it is necessary to introduce between the lungs and the tube something having the function of the air-vessel of a ram pump, namely, that of converting a pulsating into almost a uniform flow."—Research Committee Second Report.

Dr. Haldane and Dr. Briggs have, each of them, devised an equalizing arrangement for converting a pulsating flow of air into a steady flow along an air tube attached to a mouthpiece. These arrangements are described in the Second Report of the Research Committee.

Respirators.

Respirators are designed for use in atmospheres which contain sufficient Oxygen to support life, together with other gases of a poisonous nature. The object of the respirator is to absorb the poisonous gases.

In its simplest form it consists of a pad of woollen fabric saturated with a solution of equal volumes of sodium carbonate and sodium bi-carbonate.

This is serviceable in smoky atmospheres containing an excessive quantity of Carbon Dioxide, but is useless if other poisonous gases are present.

Respirators embodying various modifications, but all on the same principle, are made by different manufacturers.

In the Army Pattern Mark III, the absorbent is contained in a box, or cartridge, carried on the chest, fitted with a non-return valve.

In Mine Rescue Work the very poisonous Carbon Monoxide gas is frequently present, and the Mine Rescue Research Committee has recommended that the use of respirators, which are not effective against this gas, e.g., the Army Pattern Box Respirator, and also the Eeds Respirator, should not be used in Mine Rescue Work, as they are not effective against Carbon Monoxide.

An old method of facilitating entrance into a dense atmosphere of smoke is to throw a wet cloth over the head.

Respirator Hood.

In the Respirator Hood (as made by Messrs. Siebe Gorman & Co., Ltd.) this primitive method has been developed.

The hood is made of twill or flannel, or some fabric which can be saturated with a solution capable of absorbing the poisonous gas to be encountered.

Goggles of glass or mica, secured to the hood with a gas-tight junction, enable the wearer to see, and a patent combination inlet and outlet valve is sometimes attached.

A danger associated with helmets and hoods covering the head of the wearer is the risk of an excessive accumulation in the cavity of the helmet of the Carbonic Acid gas which is exhaled in the breath of the wearer.

Reviving Apparatus.

It is enforced by the Government Regulations that at every mine maintaining a Rescue Brigade there shall be provided one Oxygen Reviving Apparatus, and at every Central Rescue Station four of such Apparatuses.

Of the numerous types on the market, brief reference may be here made to the following :—

(1) The Pulmotor is a totally automatic device. The lungs are filled and emptied by compressed Oxygen working through an injector.

The rate of respiration is governed by the dimensions of the lungs. When the lungs are filled, the injector begins its suction action, which is reversed automatically to pressure as soon as the lungs are emptied.

(2) Dr. Bratt's Resuscitator is somewhat like the Pulmotor, but is worked by hand. A tap supplying Oxygen, and another tap causing suction, are manipulated by a lever.

(3) The Lungmotor is a double acting pump with two pistons, driven by hand. One piston draws in Oxygen at the upstroke, and delivers it to the lungs on the downstroke, whilst the other is simultaneously drawing air from the lungs on the upstroke and exhausting into the atmosphere on the downstroke.[1]

A serious objection to apparatus, such as these three, which exercise in this mechanical way a suction on the lungs, is that they are liable to injure the air sacs, and thus do harm to the patient.

The simplest form of *Oxygen reviver* consists of a rubber bag capable of holding about one-sixth of a cubic foot of Oxygen, and furnished with a rubber tube at each end, each tube being supplied with a tap.

The Oxygen is administered to the patient with the aid of a face-mask, covering the mouth and nose.

This appliance used in combination with Schaefer's

[1] See paper by F. P. Mills on " Resuscitation from Mine Gases," *National Association of Colliery Managers*, January 1917, vol. xiv.

method of artificial respiration is considered to be the best and the simplest means of resuscitation at the present day.

Salvators.

Salvators are small steel cylinders containing 5 cubic feet of compressed Oxygen at 120 atmospheres pressure, which can be carried by a rescue party wearing Breathing Apparatus. A Salvator is carried in a sling case over the shoulder, and in the event of the supply of Oxygen of the Breathing Apparatus running short through some unforeseen cause, connection is made between the Salvator and the Oxygen inlet of the breathing bag by a rubber tube.

Oxygen High Pressure Pumps.

These are required at all stations where compressed Oxygen is used. The Oxygen is supplied by the British Oxygen Co. in cylinders containing 100 cubic feet at 120 atmospheres pressure. By means of the pump it is transferred from these storage cylinders into the cylinders of the Breathing Apparatus, which contain 10 cubic feet at 120 atmospheres pressure, or into the cylinders of Reviving Apparatus.

Meters.

Meters are essential for measuring accurately the quantity of Oxygen passing in the Breathing Apparatus, more especially the quantity passing the reducing valve in Apparatus of the Proto type. This should not be less than two litres per minute.

The meters in general use may be divided into two types :—

(*a*) The " Drum type " in which a drum is made to revolve by the flow of the gas. Through a train of counter-

wheels connected with the drum shaft the movement is conveyed to a pointer, which registers on a graduated dial face the quantity of gas passing through the meter.

The movement of the drum is steadied by its being partly under water.

(*b*) The "Float" type in which a float of pith or wood, or in some cases brass, is driven up a vertical conical tube by the gas entering at the bottom. The tube is graduated to show the flow of gas in litres per minute, the position of the float being determined by the two forces acting on it, viz., its weight and the upward pressure of the gas.

Improved meters have been designed recently by Dr. Haldane and by Dr. Briggs.

Descriptions of them will be found in the First Report of the Rescue Research Committee..

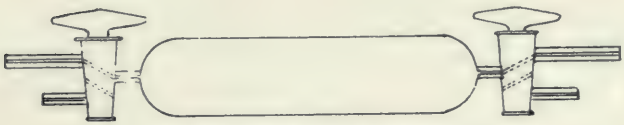


FIG. 12.—AIR SAMPLING TUBE.

Air Sampling Tubes.

A useful function of Rescue Parties is to get samples of the atmosphere underground to be tested on returning to the surface. For this purpose a convenient appliance is a glass tube, capable of holding about 100 cubic centimetres, and closed with taps at either end (see Fig. 12). It is evacuated of all air, and the taps closed, until it is required for use. To take a sample, it is then only necessary to open one of the taps for a second or two, and to close it again.

Hand Pumps.

For dealing with underground fires, hand pumps are useful. The Elswick double-acting hand pump

weighs 35 lb. and measures over-all 13 in. × 17 in × 17 in. It is capable of delivering 25 gallons of water per minute when driven at 125 double strokes per minute, and can throw a $\frac{3}{4}$-in. jet of water a distance of about 40 feet. The suction and the delivery valves are made entirely of metal. The suction hose-pipe is $2\frac{1}{4}$ inches in diameter, and the delivery $1\frac{1}{4}$ inches. For the suction water a portable canvas dam measuring 3 feet × 18 inches × 18 inches is provided. This has proved to be a very useful pump for transport and for dealing with fires underground.

Portable Telephones.

In Rescue operations it is a great advantage to be able to communicate by telephone between the advance base and the pit-bottom, or even the surface.[1] A transmitter and receiver and battery are carried in a leather case measuring 7 inches × 7 inches × $3\frac{1}{2}$ inches. Reels of cable are carried on drums. By means of special plugs the telephone can be connected to the drum at any point when paying out the cable, and communication made with the other end. When a reel is run out, it is taken off the carrier, and another reel put in its place, and connected in series with the last one payed out.

The Laryngaphone.

The Laryngaphone is a form of portable telephone which has been put on the market recently by the Telephone Manufacturing Co., Ltd. Its object is to enable men wearing Breathing Apparatus to carry on conversation between themselves, either when close at hand or at a distance. A transmitter of a

[1] See *Trans. Inst. Mining Engineers*, vol. xli, p. 266. *Durham and Northumberland Fire and Rescue Station*, by W. C. Blackett.

special type is fixed to the side of the larynx—the air-tube in the front of the neck above the windpipe —and transmits through a flexible cable the vibrations of the vocal chords to two receivers combined, which are fixed one in each ear. The whole apparatus is light and portable, the total weight of it when carried in its box being about 14 lb.

Without the aid of a telephone, men wearing Breathing Apparatus have great difficulty in making themselves understood. The only means is by pre-arranged signals, using a hooter or motor-horn, which limits the distance to about 100 yards, or by flashes of an electric lamp. This, again, is only practicable where no obstacles intervene between the lamp and the base of operations.

The bells of the portable telephone can be used, of course, up to any distance.

Portable Folding Stretchers.

Portable Folding Stretchers are required for carrying injured men. " Pole stretchers " are light, and easily carried. They consist of a couple of ash poles, 7 feet long and 2 inches in diameter, on to which is strung, through loopholes, a piece of canvas material forming the bed on which the patient is laid.

The " Valeda " stretcher made by the Liquid Air and Rescue Syndicate, Ltd., is an ingenious construction of light iron work, which can be folded up, and put into a small case convenient for carrying.

Electric Charging Sets.

For charging the accumulators of electric hand lamps, and the batteries on motor cars, a charging set is a necessary part of the equipment of most Rescue Stations.

A suitable machine is a small motor generator of 240 volts and 2·5 amperes, running at 1,500 revolutions per minute, with a charging dynamo of 11 volts and 2·5 amperes, and a charging board fitted with the necessary switches, fuses, ammeters, etc.

Liquid Air Apparatus.

The standard apparatus in use at Rescue Stations for liquefying atmospheric air consists of a fore-

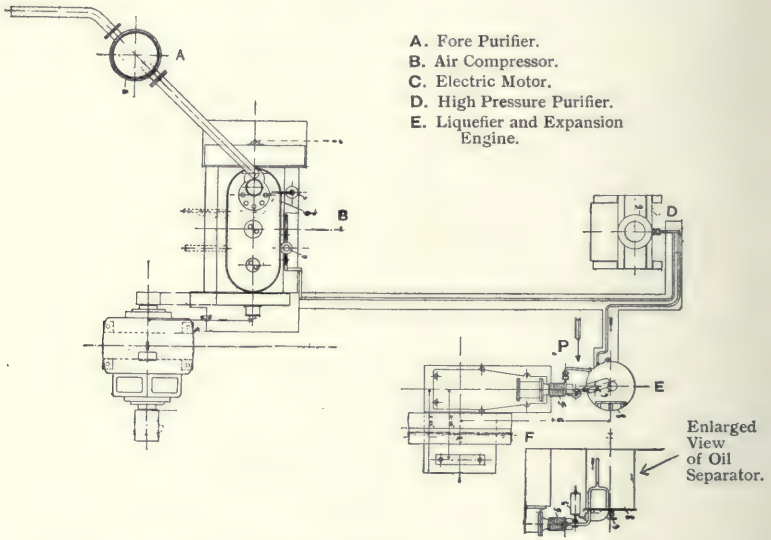


FIG. 13.—DIAGRAM OF ARRANGEMENT OF LIQUID AIR PLANT.

purifier, an air compressor, a high-pressure purifier, an expansion engine, a liquefier, and an electric motor to drive the air compressor (see Fig. 13).

A room about 19 feet square is required to hold this plant.

The atmospheric air is drawn through the fore-purifier A (see Fig. 13) by the compressor B, in accordance with its capacity.

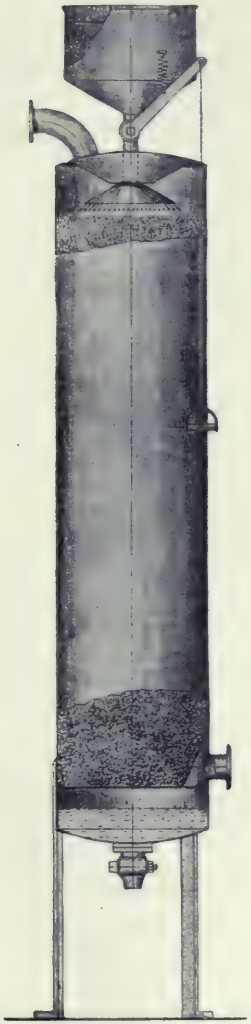


FIG. 14.—DIAGRAM OF FORE PURIFIER.

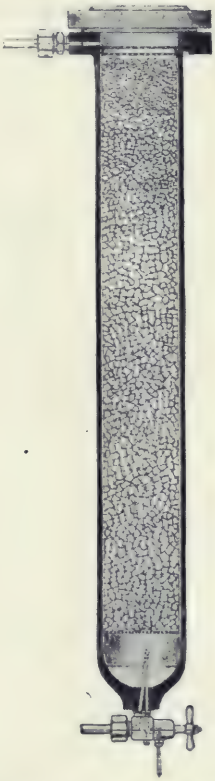


FIG. 15.—DIAGRAM OF HIGH-PRESSURE PURIFIER.

The fore-purifier A (see Fig. 14) is a long steel cylinder, filled with steel shavings, into which is poured a solution of caustic soda or caustic potash. The object of the steel shavings is to distribute the alkali solution so that it may be thoroughly mixed

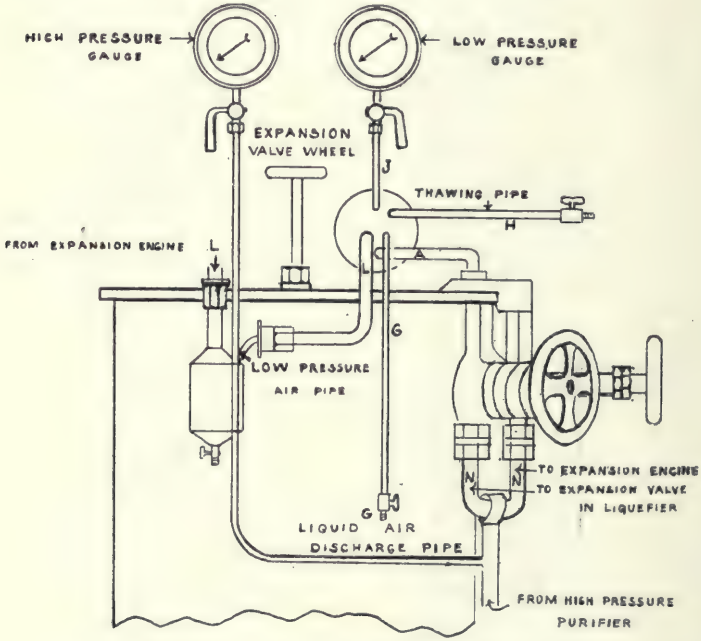


FIG. 16.—ARRANGEMENT OF PIPES AT AIR LIQUEFIER.

N.B.—The same letters apply to the Section Fig. 18.

with the air, and that the Carbonic Acid gas and moisture may be eliminated.

There is a tendency of the caustic alkali to crystallize, and thus choke the airways of the purifier. To avoid this, the specific gravity of the solution, when caustic soda is used, should not exceed 1·06,

nor 1·41 with caustic potash. This corresponds to a solution of about 10 lb. of caustic soda, or 30 lb. of caustic potash, in 20 gallons of water. The purifier also should be well washed out with pure water once a month.

The air compressor is a three-stage machine, driven by the electric motor through an endless chain, or through gear wheels, at a speed of 250 to 270 revolutions per minute. At 264 revolutions per minute its capacity is 90 cubic metres of free air.

In the first stage the air is compressed to 90 lb., in the second to 500 lb., and in the third to 3,000 lb. per square inch. It is kept cool by circulating cold water round the outside of the cylinders. A small amount of water is also used inside the cylinders as a lubricant, and mixes with the air compressed. This water is got rid of, eventually, by means of a separator placed in front of the compressor. It is blown off through a cock, at the bottom of the separator.

To avoid the formation of ice in the subsequent process of expansion it is important that the air should be dry. Hence it is taken to the high-pressure purifier or drier " D."

Sometimes another purifier containing calcium chloride is used, which much assists the drying of the air. The high-pressure purifier (Fig. 15) as ordinarily used, is a vertical steel cylinder containing a movable box or cage which is filled with lumps of caustic soda about the size of walnuts. Above the cage there is a filter of wadding. The air enters at the bottom of the cylinder, passes up through the caustic soda, which takes out the aqueous vapour and any carbonic acid gas which may be left, and leaves at the top. If the fore-purifier is doing its work properly, the

high-pressure purifier will not need a fresh charge of caustic soda till after about 120 hours of continuous running of the plant. After leaving the high-pressure purifier the air is divided, about half going to the expansion engine and half to the liquefier. The branch pipes where this division takes place are shown at NN on Fig. 16. At the expansion engine (see Fig. 17) the air circulates round a coil of copper piping, P, shown on Fig. 13, which lowers its temperature. It then passes into the cylinder of the expansion engine, by very small portions, at each stroke of the engine, through an inlet valve

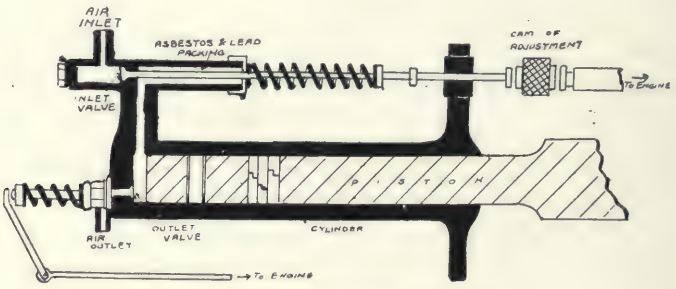


FIG. 17.—EXPANSION ENGINE.

having a lift of $\frac{3}{32}$nds of an inch. This valve is adjusted by a micrometer adjuster on the valve rod. The piston can also be adjusted by a screw in the connecting rod so as to give a minimum clearance at the end of its stroke. The clearance is half a millimetre, when the lift of the valve is $\frac{3}{32}$nds of an inch. This inlet valve opens just as the piston has emptied the cylinder through the outlet valve. During the return stroke of the piston the small quantity of air admitted is highly expanded, which reduces its temperature to about — 150° C. At the next stroke this cold air

is driven through the outlet valve and passes through an oil separator (see Fig. 13) to the liquefier. Here it meets and mixes with the other air from the high-

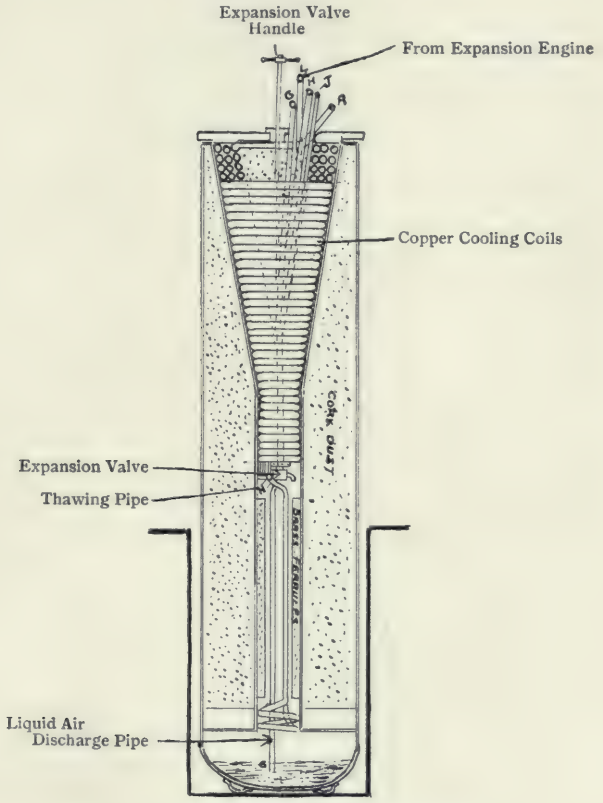


FIG. 18.—ARRANGEMENT OF AIR LIQUEFIER.

SECTION.

pressure purifier, which has been expanded and cooled by its passage through coils of copper tube in the liquefier to the expansion valve (see Figs. 18 and 19). In expanding through this valve there is a further

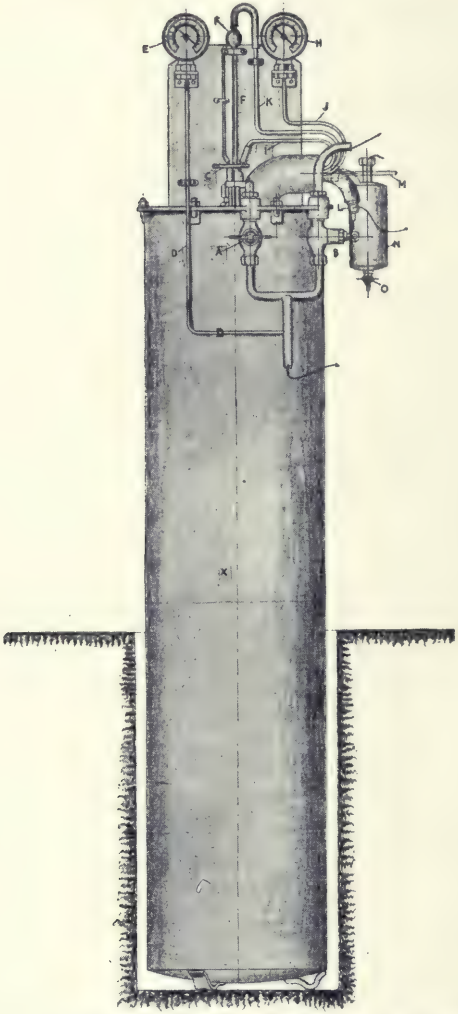


FIG. 19.—ARRANGEMENT OF LIQUEFIER. ELEVATION.

drop in temperature, and it is here, on meeting the air from the expansion engine, that the liquefac-

tion takes place at a temperature of about — 190° C. The expansion valve is controlled by a hand wheel shown on Fig. 18. As the liquid air falls towards the collecting box at the bottom of the liquefier, it passes through a rectification column. This is a vertical pipe containing brass ferrules or shavings, the effect of which is to raise the temperature to a point at which the more volatile Nitrogen evaporates, whilst the Oxygen remains in the liquid state. Thus the proportion of Oxygen in the liquid air is increased. The size and arrangement of the rectification column determine the percentage of Oxygen in the liquid.

By lengthening the column, liquid air containing more than 90 per cent. of Oxygen can be got. The cold Nitrogen gas passing from the rectifier is made to circulate through a set of copper coils in the liquefier in order to cool the incoming air, and also through the space between the inner and outer casings of the liquefier for the same purpose. If the moisture in the air is not all taken out in the purifiers it will be frozen into ice in the liquefier and stop the circulation. To meet this difficulty a large tube —the thawing tube (see Figs. 16 and 18)—is carried well down inside the liquefier, and by means of it hot air from the compressor can be brought into the liquefier in the event of freezing having occurred.

The expansion engine runs at a speed of 160 to 190 revolutions per minute. The driving power is the high-pressure air at 3,000 lb. per square inch, but the speed is governed by connection with the electric motor through an endless belt running on a pulley on the crankshaft of the engine (see Fig. 13). In fact, the expansion engine assists the motor as much as 5 horse-power. The motor is 40 H.P. direct current, at 50 amperes and 460 volts, at 800 revolutions per minute. The normal output of

the plant is 20 lb. of liquid air per hour, containing 60 per cent. Oxygen; and the consumption of power is one electrical unit (kilowatt-hour) per lb. of liquid.

But by varying the lift of the inlet valve on the expansion engine increased output with diminished percentage of Oxygen, or the converse, may be obtained.

For example, in four tests of the plant the following results were obtained :—

(1) 35 lb. of liquid per hour showing on analysis 35 per cent. of Oxygen.
(2) 30 lb. of liquid per hour showing on analysis 50 per cent. of Oxygen.
(3) 30 lb. of liquid per hour showing on analysis 50 per cent. of Oxygen.
(4) 20 lb. of liquid per hour showing on analysis 70 per cent. of Oxygen.

Figures of the production of liquid air and its cost for six months are given below.

Hours run of Plant.	Lb. Liquid air made.	Lb./Hour.	Elect. Units used.	Lb./Unit.
447	8,705	19·47	11,175	0·78

	Total Cost for Half Year.
To plant repairs .. .. [1]	£53 0 8
,, Electrical power at 1·78d. per unit	82 17 7
,, Caustic Soda—228 lb. at 1s. 1d. per lb. ..	15 12 0
,, Calcium Chloride—56 lb. at 15s. per cwt. ..	0 7 6
,, Clot Lime—84 lb. at 4s. per cwt.	0 3 0
,, Oil—20 gallons at 2s. 8d. per gallon. (Oil has now increased to 4s. 1d. per gallon) ..	2 13 4
,, Water—178,800 gallons at 1s. 3d. per 1,000 gallons	11 3 6
	£165 17 7

= 4·5d. per lb.

[1] The cost of repairs is high, as the plant is 10 years old.

But this cost does not include depreciation, wages, etc.

In an article on "The Use of Liquid Air for Blasting" (see *Colliery Guardian*, September 3, 1920) the actual cost of production with a 20 lb. per hour Lars liquid air plant is given as follows: Total production during 1919, 20,786 lb. liquid air; total cost, including wages, power at 1·78d. per unit,

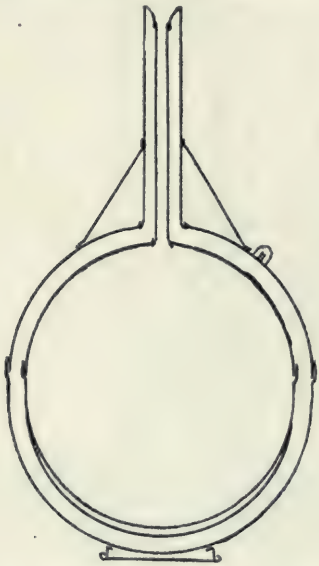


FIG. 20.—LIQUID AIR CONTAINER.

maintenance, depreciation, etc., £530 = 6·2d. per lb.

The cost would be considerably less if the plant was run continuously to its full capacity.

Containers.

Liquid air being extremely volatile, its economical storage and transport present some difficulty. Sir James Dewar invented a metallic vacuum flask for

storing and carrying liquefied gases for laboratory use. The containers (see Fig. 20) in present use for storing and carrying liquid air in Mine Rescue Work are designed after the pattern of Sir James Dewar's flask.

They consist of an inner and outer vessel, both made of spun brass. When required for use the

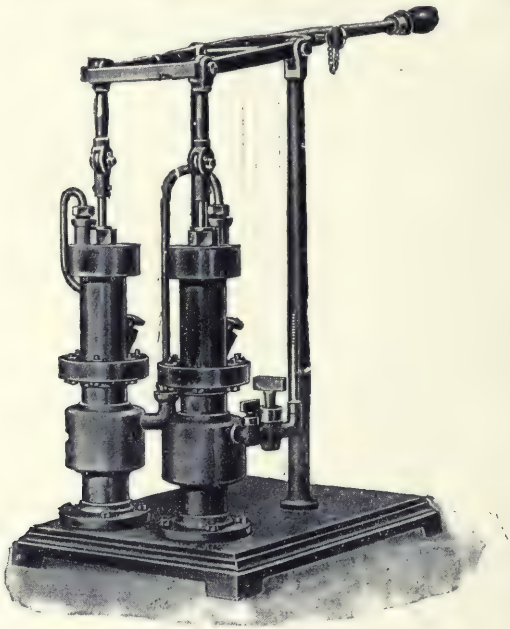


FIG. 21.—GERYK VACUUM PUMP.

intervening space is evacuated, connection being made with a vacuum pump. This vacuum round the inner vessel prevents conduction of heat. To minimize radiation the outer vessel is highly polished on its inner surface, and the inner or containing vessel on its outer surface. In an inverted dome fastened beneath the inner vessel some charcoal is

placed—a highly absorptive material which promotes a high vacuum. Each container holds 50–56 lb. of liquid air. The loss by evaporation when standing averages about $3\frac{1}{2}$ lb. in twenty-four hours. These containers are carried in strong wicker baskets especially constructed with a view to avoiding jolts and jars.

The Duplex No. 1 " Geryk " Vacuum Pump.

Fleuss Patent (see Fig. 21).

This is one of the well-known vacuum pumps made by the Pulsometer Engineering Co., Ltd., of Reading. This air pump utilizes the hydraulic principle, i.e., the properties attached to fluids in motion. The fluid used is a special oil with the lowest possible vapour tension, in fact it is claimed that when the pump is at work the vapour pressure is a negligible quantity. It has two 2-inch cylinders by 5-inch stroke. It works with the minimum of friction, and should be driven smoothly, and not too fast. A vacuum of within one-thousandth (0·001) of a millimetre can be obtained with it.

The Pulsometer Engineering Co. has recently introduced an improved " Geryk " pump, capable under favourable conditions of producing a vacuum of one millionth of a millimetre.

The McLeod Vacuum Gauge.

Shown on Fig. 22 is a simple contrivance for accurately measuring a vacuum.

In using it the mercury reservoir is raised by the hand till the mercury rises up both of the glass tubes, one of which is closed at the top, whilst the other remains open to the vacuum to be measured. If it is a perfect vacuum, the mercury will stand at the same level in both tubes. If not, some air will be

imprisoned in the sealed tube, preventing the mercury from rising to the height it reaches in the other tube. A sliding scale marked in metres is provided to measure the difference in level. One or two millimetres difference is a fairly good result in evacuating liquid air containers.

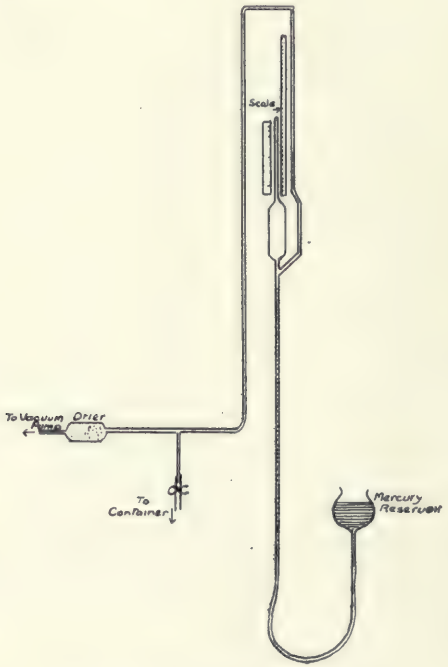


FIG. 22.—MCLEOD VACUUM GAUGE.

Pressure Gauge Tester.

A simple appliance for testing the accuracy of pressure gauges is shown in Fig. 23

It was designed, and is used with satisfactory results, at the Elswick Rescue Station, Newcastle-upon-Tyne.

The illustration is self-explanatory. Plugs can be used to stop three holes when one gauge requires to be tested, and adaptors to fit the various types of screws can be made to connect with the tester. Accuracy is essential in gauges used to find the pressures in Self-contained Breathing Apparatus, and compressed oxygen cylinders.

Oxygen Analysis Apparatus.

For determining the percentage of Oxygen present

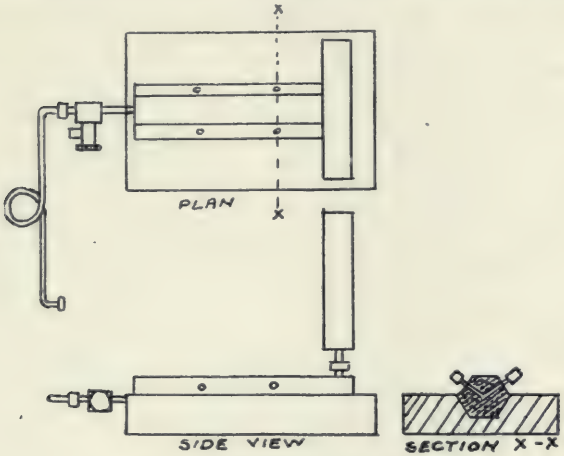


FIG. 23.—PRESSURE GAUGE TESTER.

in storage cylinders, or in samples of volatilized liqu'd air, the Briggs Apparatus has been found the simplest type giving accurate results. It is described fully, with a diagram, in the First Report of the Mine Rescue Research Committee, page 50.

Another useful apparatus for the same purpose, i.e., for estimating the amount of Nitrogen in compressed Oxygen, has been designed by Mr. J. Ivon Graham. It is also described in the same Report,

where it is stated that "a determination of the Nitrogen content of an Oxygen cylinder sample may be made in a few minutes and with no greater error than 0·1 per cent."

CO Analysis Apparatus.

Mr. Graham has also designed an apparatus for the accurate determination of Carbon Monoxide in gas mixtures.[1] 0·2 per cent. of this gas in air is highly dangerous to breathe, and even smaller quantities than this are injurious if breathed for some length of time. Its presence in mines after fires and explosions is one of the greatest, certainly the most insidious, dangers that rescuers have to meet. Hitherto the only means of detecting it has been by its effect on small birds and mice.

Mr. Graham's apparatus is therefore most welcome and valuable.

It is made for use underground. It is claimed for it that an analysis can be completed in about five minutes, and "an accuracy of 0·005 per cent. obtained without much difficulty when using only 100 cubic centimetres of sample; when using one litre of sample, an accuracy of 0·0005 per cent. may be obtained."

Both of these apparatuses of Mr. Graham are made by Messrs. Reynolds and Branson, Ltd., of Leeds, from whom full particulars may be obtained.

Means of Detecting Carbon Monoxide.

BIRDS AND MICE.

Probably the most practical and convenient method of detecting the presence of Carbon Monoxide

[1] See *Journal of the Society of Chemical Industry*, 1919, vol. xxxviii, "The accurate determination of Carbon Monoxide in Gas Mixtures," by J. Ivon Graham.

is by observing its effect on small animals or birds. They become affected nearly seven times quicker than does the human being. The following table issued by the U.S.A. Bureau of Mines, Tech. Paper No. 11, shows the relative susceptibilities of mice and canaries to Carbon Monoxide poisoning :—

Mice.		Canaries.	
Per cent.	*Effect.*	Per cent.	*Effect.*
0·16	Very slight distress at end of 1 hour.	0·09	Very slight distress at end of 1 hour.
0·2	Distress in 8 minutes. Partial collapse in 15 minutes.	0·12	Weaker at end of 1 hour than above.
0·31	Distress in 4 minutes. Collapse in 7½ minutes.	0·15	Distress in 3 minutes. Fell from perch in 18 minutes.
0·46	Distress in 2 minutes. Collapse in 4 minutes.	0·2	Distress in 1½ minutes. Fell from perch in 5 minutes.
0·57	Distress in 1 minute. Collapse in 2 minutes. Death in 16 minutes.	0·29	Fell from perch in 2½ minutes.
0·77	Distress in 1 minute. Death in 12 minutes.		

These tests show that canaries may be better than mice as indications of the presence of noxious gases in mines, since they more quickly show signs of distress in the presence of small quantities of Carbon Monoxide.

In addition the symptoms in birds are more clearly defined. A bird sways noticeably on its perch before falling, and its fall is a better indication of danger than is the squatting, extended posture that some mice assume (without much struggling), attempts to walk, or other preliminary symptoms.

Consequently birds not only give more timely warning of the presence of small quantities of Carbon Monoxide, but exhibit symptoms that are more easily noticed by exploring parties.

The Mine Safety Appliances Co., of Pittsburgh, Pa., has recently introduced a simple appliance for detecting Carbon Monoxide (see Fig. 24).

This consists of a nickel-plated cylinder (A) which is filled with a chemical designed to absorb gases likely to be present, other than Carbon Monoxide. On the top of this cylinder is a glass tube (B), containing a specially prepared chemical which changes colour in contact with Carbon Monoxide. According to the amount of Carbon Monoxide present this colour varies from light green to deep green. A colour scale is supplied, by which the percentage of

FIG. 24.—M.S.A. CARBON MONOXIDE DETECTOR.

CROSS-SECTION.

Carbon Monoxide present may be approximately determined.

The air to be tested is drawn through the cylinder (A) and forced through the glass tube (B) by means of the rubber bulb (C).

Carbon Monoxide Gas Mask.

Another promising appliance which is supplied by the same company is a Carbon Monoxide Mask. The canister contains a material which converts Carbon Monoxide into Carbon Dioxide. The air is drawn through this canister by the lungs of the wearer into the face-piece, and breathed out through an exhalation valve. The whole apparatus weighs only $3\frac{1}{2}$ lb., and can be put on very quickly ;

but as yet there is no practical information available regarding the mask, beyond statements of the makers.

Electric Head-lamp.

An electric head-lamp has the great advantage for Rescue Work, in comparison with a hand-lamp, that it leaves both hands free.

Electric head-lamps have been in use at the Edinburgh Rescue Station for more than a year, and Mr. J. Cooper, the Superintendent of the Station, has borne testimony that they have given great satisfaction, and are eminently suitable for all phases of Rescue Work. In a paper read before the Institution of Mining Engineers (vol. lvii, p. 58) he points out the superiority of a head-lamp in such operations as handling a water-hose when quenching a mine fire, building a stopping, putting up "brattice" or air tubes, carrying a man on a stretcher, or applying artificial respiration underground. The battery-case is carried on the right hip, attached to an ordinary belt.

Other electric head-lamps which have been introduced lately are the "Oldham," which has been fully described by Mr. George Oldham (see *Trans. Inst. Mining Eng.*, vol. lix, p. 334), and another for which Mr. John C. Blake, of Girvan, Ayrshire, is sponsor. It is claimed for the latter that it gives a light of $2\frac{1}{2}$ candle-power, will show up a coal face at a distance of 12 feet, and that the light lasts for sixteen hours.

The Geophone.

The Geophone is an instrument for detecting sounds at considerable distances through the solid strata of the earth's crust. It was invented by the

French during the War, and was found very useful in detecting and determining the direction of the underground mining operations of the enemy.

It was improved by American engineers, and more recently it has been tested and developed by the U.S.A. Bureau of Mines for use in Mine Rescue Work.

In mine disasters it is not unusual for a party of men, or sometimes a single individual, to become imprisoned in a small portion of the mine, shut off, it may be, by a heavy fall of stone, or by accumulation of water or of poisonous gas. In such cases they endeavour to make their presence known by knocking with a pick or hammer on the coal or rock which surrounds them. Signalling in this way by an agreed number or rhythm of knocks is a common practice in coal-mining. In the Newcastle coalfield it is known as "jowling."

To a Rescue Party seeking entombed men the Geophone is likely to be a valuable aid.

Investigations by the U.S.A. Bureau of Mines show that blows of a pick can be detected through 1,200 feet of solid strata, and pounding with a sledge hammer through 2,000 feet. Talking can be understood fairly well through 50 feet of solid coal, and can be detected at a distance of 150 feet.

It has been found that better results are got with the Geophone placed on solid coal or rock rather than on the floor, the latter being seldom solid enough to transmit sound well.

An imprisoned man wanting to make known his position to a Rescue Party seeking him should knock on the solid coal.

The Geophone has also been used to advantage in mines in discovering the location of fires by the noise they make.

It is constructed on the same principle as the seismograph, which is used to record earthquake movements, but the Geophone is a much smaller and simpler instrument.

The essential feature of both is a fairly heavy mass of metal so suspended that, although its supports are moved, some point in the mass remains practically at rest.

In the Geophone a lead weight is suspended within an iron ring by a single bolt passing through two metal discs, one of which covers the top, and the other the bottom of the ring. The dimensions of the ring are about $3\frac{1}{2}$ inches diameter by $1\frac{1}{2}$ inches deep. The discs are made of pure nickel 0·025 inch thick.

There are two brass cap pieces, fastened by bolts to the iron ring, one above and the other below. We have thus a lead weight suspended between two thin discs which stretch across an airtight case.

The upper cap piece has an opening in the centre, to which is fastened a rubber tube, leading to an ear-piece, like that of the stethoscope used in medical practice.

These brass cap pieces serve also to hold the metal discs in place.

The lead weight remains practically motionless, while movement is set up in its case by the alternative compression and expansion of the air in the thin space over the disc.

These vibrations of the air are magnified at the small outlet to which the rubber tube is attached, and are conveyed through the stethoscopic ear-piece to the drum of the ear.

Usually two instruments are used, one for each ear.

Aeroplanes.

There can be little doubt that sooner or later aeroplanes will be utilized for the rapid transport of men and apparatus from a Rescue Station to a mine on the occasion of a disaster.

A beginning in a small way has been made already in America. In the autumn of 1919 an agreement to co-operate as far as possible was made betewen the Bureau of Mines and the Air Service. The Air Service maintains in readiness aeroplanes to assist Rescue Stations within feasible distances. The aeroplanes must be, of course, of a type suitable for carrying passengers and rescue apparatus.

A serious difficulty to be met is the lack of suitable landing places at the stations and at the mines. It has been stated that the present types of aeroplanes require a landing place about 1,800 feet in extent in both directions. This means an area of about 75 acres, or about one-third of a mile long and one-third of a mile broad. The development of aeroplanes will lead probably to the construction of a type capable of landing and ascending within a small area, and this will facilitate their use in Mine Rescue Work.

VII

THE DESIGN AND EQUIPMENT OF RESCUE STATIONS

THE provision of suitable and properly equipped Stations is a most important factor in Mine Rescue Work.

These buildings should be adapted in their design to the varying conditions for which they are required.

There are four sets of conditions to be considered :—

(1) For a single colliery, or a small group of collieries, not connected with a Central Station, a building is required for housing Rescue Apparatus and equipment, and a gallery for training men in Rescue Work.

(2) A Central Station, not maintaining a permanent resident brigade, may be needed to train men from collieries surrounding it within a 10-mile radius. Here one or more permanent instructors will reside and a Rescue Car will be kept.

(3) A Central Station, fulfilling the conditions of No. 2, and in addition, maintaining a permanent Rescue Brigade of six or eight men.

(4) A Central Station, covering the requirements of No. 2 and No. 3, and in addition equipped with a Motor Fire Engine and all fire-fighting appliances, and with men trained to deal with colliery fires.

Type (1) is required for collieries so situated that attachment to a Central Station is impracticable.

For such a Station the equipment will be much as follows : Six complete sets of compressed Oxygen

Self-contained Breathing Apparatus, twelve 100 cubic feet storage cylinders of oxygen compressed to 120 atmospheres, one oxygen pump to charge smaller cylinders, one cwt. of caustic soda for purifiers in breathing apparatus, two reviving apparatuses, one smoke helmet and air pump, one meter for

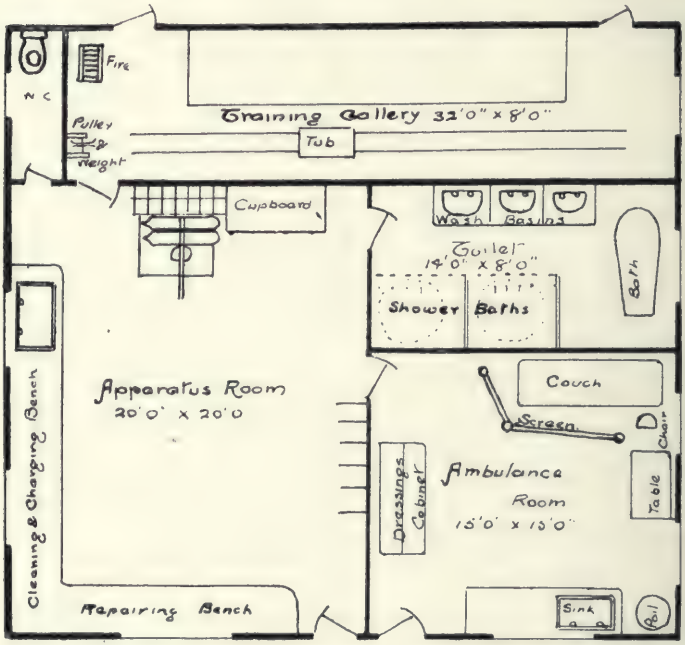


FIG. 25.—PLAN OF RESCUE STATION, TYPE I.

(Scale $\frac{1}{8}$-inch = 1 foot.)

testing flow of Oxygen in apparatus, six electric hand-lamps, two safety lamps, three canaries, a cupboard containing spare parts, a repairing bench with a vice and repairing tools, a stretcher, bandages and splints for practice work.

The new Regulations of July 1920, provide that :—

" At every mine to which the existing Regulations apply there shall be a room provided and maintained exclusively for Rescue and Aid purposes."

Fig. 25 is a ground plan of a Rescue Station suitable for a single mine or a small group of mines, and providing also an ambulance room as specified in this Regulation.

This is an original design by Mr. F. P. Mills, one of the authors of this book.

Such a Station needs a capable instructor to be placed in charge of it.

It can hardly equal in efficiency a central properly-equipped station, but with frequent practices given to the rescue men of the mine it may fulfil its purpose satisfactorily.

(2) Examples of type (2) are the Stations at Heriot-Watt College, Edinburgh, Cowdenbeath, Howe Bridge, Porth, etc.

A suitable design is shown in plan in Fig. 26.

In Stations of this type a Rescue Car is kept ready equipped for emergency calls.

A minimum equipment of the car will comprise the following :—

Six Self-contained Breathing Apparatuses complete, one smoke helmet complete with 180 feet of tubing, four reviving apparatuses, one set of portable telephones and cable, six electric hand-lamps, two safety lamps, two canaries, one stretcher and ambulance outfit, one 1,000 feet reel of $\frac{3}{8}$-inch cotton rope.

Besides this, the equipment of the Station will include :—

Nine Self-contained Breathing Apparatuses complete, twenty 100 cubic feet cylinders of compressed oxygen, half a ton of caustic soda, one oxygen pump, one meter for testing, three smoke helmets, one set of portable telephones, twelve electric hand-lamps,

one charging set for electric lamps, set of tools for repairing purposes, six canaries for testing atmosphere underground, flow diagrams of apparatus and mine

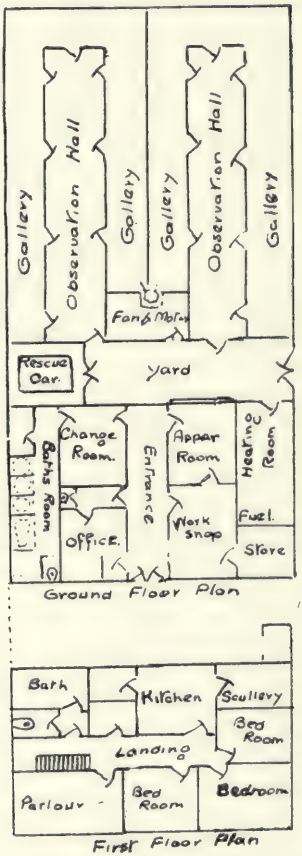
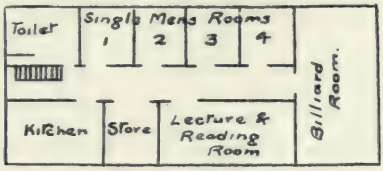


FIG. 26.—RESCUE STATION, TYPE 2.

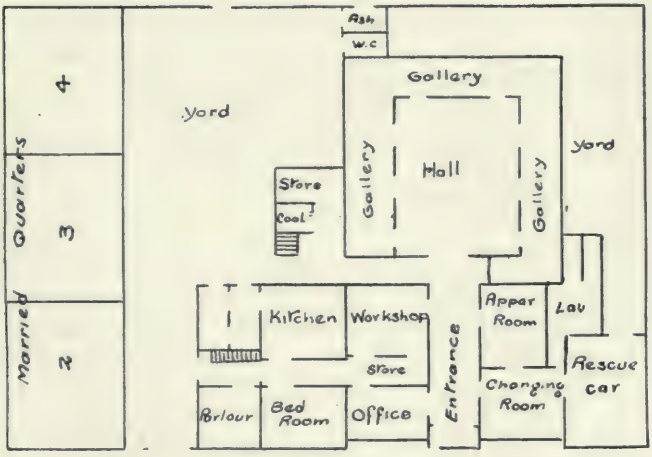
plans for purposes of instruction, appliances to demonstrate the effect of carbon monoxide, carbon dioxide, and carburetted hydrogen on lamps and animals, and a training gallery.

No. 3.—In a Station of this type accommodation has to be provided for a permanent staff ready to turn out night or day to emergency calls within the 10 miles radius.

In other respects its equipment is much the same as that of Stations of (2) class. The perfection of



First Floor Plan.



Ground Floor Plan.

FIG. 27.—RESCUE STATION, TYPE 3.

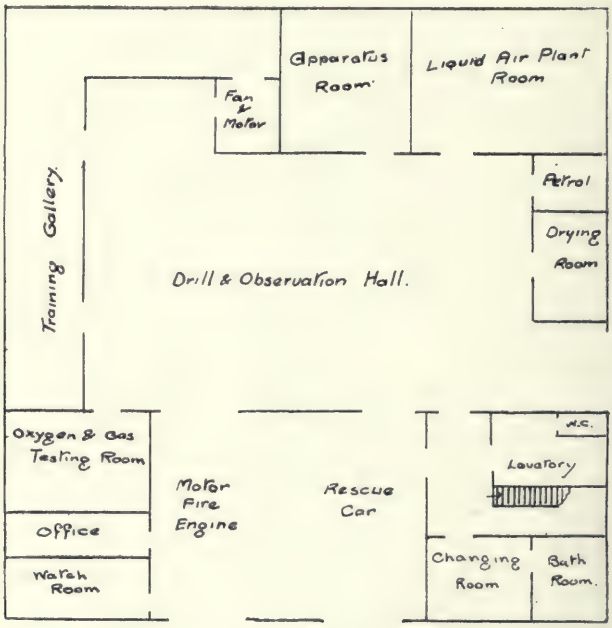
the equipment depends, of course, on the zeal and the enthusiasm of the colliery owners, who bear the entire cost of these Stations.

For economical reasons a staff of unmarried men is desirable, but experience has shown that it is

difficult to retain for long the services of unmarried men. They tire of the long periods of stand-by duty, and desire more freedom than can be allowed.

It is a better arrangement that at least half of the staff should be married men.

This entails the provision of married quarters in close proximity to the Station.



Ground Floor Plan.

FIG. 28.—RESCUE STATION, TYPE 4.

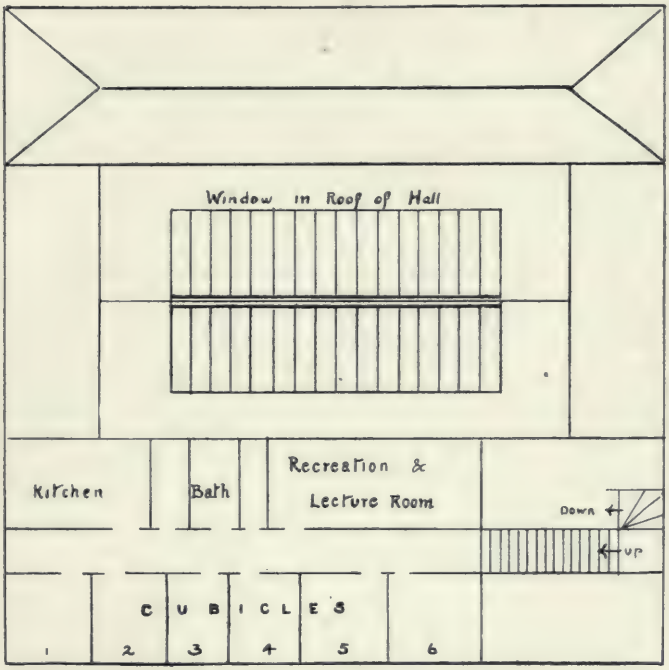
Eight men is the lowest number required for a permanent resident brigade, to allow for adequate leave, and for sickness and other contingencies.

Fig. 27 suggests a design for such a Station, where four of the staff are married and four are single men.

The married quarters should be connected with the Station by some system of alarm bells to bring the brigade quickly together in the event of a call.

These permanent staffs usually wear a distinctive uniform.

No. 4.—The Durham and Northumberland Coal



First Floor Plan.

FIG. 29.—RESCUE STATION, TYPE 4.

Owners Association, when building their first Rescue Station in 1909, realized that fire is a much more frequent disaster at collieries than explosions, and all their Stations are fully equipped for dealing with fire as well as with explosion.

Stations of this type have been provided also by the North Midland and by the Leicestershire Coal Owners.

Figures 28 and 29 are line drawings of a Station of this class which has been erected at Houghton-le-Spring, co. Durham.

Equipment of Rescue Car.

"A Motor Car shall be kept in constant readiness," is one of the Government Regulations. What should be carried on these cars, and how best stowed away, is a matter that calls for careful consideration.

The following descriptions of the equipment of the Elswick Rescue Car (Fig 30) and of the Elswick Fire Engine Car may serve to show what is required.

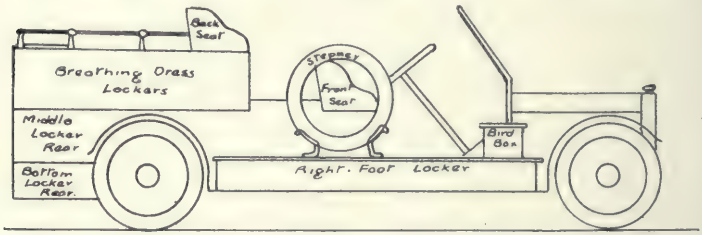


FIG. 30.—RESCUE CAR. SIDE VIEW.

Equipment of Elswick Rescue Car.

Top of Car.—Elswick Hand Pump, 10 ft. of 2¼-in. suction hose, two 50-feet lengths of 1¼-inch delivery hose, 1 canvas dam, 1 branch with ¼-inch nozzle, a suction key, 1 valve key.

In box.—1 converter adaptor for hand pump to 2½-inch instantaneous hose, 1 70-feet line, 1 spade, 1 universal hose adaptor, 2 skid chains in bag, 1 hydrant key, 1 bag of sand, 1 box containing 3 route and order books.

Round body of Car.—6 Proto dresses complete with keys, 25 feet life-lines, goggles, knee pads.

Top Locker (Rear).—1 half-mile drum of telephone wire on carrier with handle, 2 water lights, miscellaneous box containing 2 canvas buckets, 2 pairs rubber gloves, 2 water bottles, 6 electric hand-lamps, 2 safety lamps, 2 Army respirators, 3 small respirators, bottle of mixture for respirators, box of lead rivets, 1 pair of nippers and cutters, 2 dry cells for portable telephones, and 1 set C.A.V. bulbs in box.

Middle Locker (Rear).—Five $\frac{1}{8}$-mile telephone drums, 2 of same with carriers and handles complete, 3 complete salvators, and 2 spare cylinders for same, 3 Draeger Reviving Apparatuses, 1 Simonis Reviving Apparatus, 1 Vivox Reviving Apparatus (Siebe Gorman).

Bottom Locker (Rear).—20 electric hand-lamps (Joel fors), 1 box containing 6 air sample bottles, 1 box containing hooters and oxygen cards.

Right Foot Locker.—10 4-lb. tins caustic soda sticks, 2 tin openers, 2 cork screws, 2 60-feet lengths $2\frac{1}{2}$-inch instantaneous hose, 2 25-feet cotton lines on leather drums, 1 oval container with 4 connecting pieces for portable telephones, 1 long line, 1 control valve, 1 hydraulic lifting-jack.

Top of Right Foot Locker.—1 box for birds, 3 small cages, 1 Dunlop Stepney.

Left Foot Locker.—1 $\frac{1}{4}$-mile drum of telephone wire on carrier with handles complete, 2 100-feet lengths of $2\frac{1}{2}$-inch instantaneous hose, 2 60-feet lengths of $2\frac{1}{2}$-inch instantaneous hose, 3 short branches, $2\frac{1}{2}$-inch (1 1-inch nozzle, 2 $\frac{3}{4}$-inch nozzle), 1 converter adaptor, $2\frac{1}{2}$-inch screw to $2\frac{1}{2}$-inch instantaneous, canvas for 3 emergency stretchers.

Top of Left Foot Locker.—Box containing: 3 maps in case, 6 spare bulbs for Joel fors lamps, box of assorted washers for apparatus, 5 bags chalk, 2 return door keys, spare nozzle for hand pump $\frac{3}{8}$-inch, 1 Goodyear Stepney.

Under Back Seat.—1 Valeda stretcher (collapsible), 1 sealed ambulance box, 3 portable telephone boxes, leather bag containing 6 books and 6 pencils for portable telephones, 6 books and 6 pencils for officers' use, 1 envelope with list of colliery men trained, 1 envelope with Rescue Work notices complete.

Under Side Locker.—6 poles for emergency stretchers.

Equipment of Elswick Fire Engine Car.

Weight of car	5 tons.
Length of car	20 feet.
Breadth of car	6 feet 9 inches.
Height of car	8 feet 9 inches.
H.P. of engine	60–75 H.P.
Crew	1 driver, 1 officer, 6 firemen.

Around Body of Car.—2 20-feet lengths of 5-inch suction, 1 with strainer, both having universal screw connections, hose reel carrying 7 100-feet lengths of 3-inch Morris' instantaneous hose, 1 3-inch instantaneous branch with 1½-inch nozzle.

Top of Car.—40-feet extension ladder, 1 pompier hook ladder, 1 first-floor pole ladder, 3 body belts with spring hooks, 1 canvas dam, 1 jumping sheet 10 feet diameter, 4 town pattern standpipes fitted with ball valve arrangement, 1 Jumbo branch stand, 1 70-feet life-line, 1 150-feet life-line, 1 bag of sand, 3 Pyrene extinguishers, 1 basket strainer and chafing leather for suction.

Hose Box.—12 100-feet lengths 2½-inch instantaneous hose, 2 60-feet lengths of 2½-inch instantaneous hose, 2 water lights and 2 canvas buckets, 1 ambulance chest, 1 30-feet cotton line for suction, 1 wire tow rope, 2 pairs rubber gloves, 1 box containing 3 Army pattern respirators, 2 respirator hoods with mica fronts, 2 bottles mixture for same, 2 50-feet lengths of 1¼-inch instantaneous hose.

Left Foot Locker.—1 Swift control branch, 2½-inch instantaneous with ¾-inch nozzle, 1 control branch 2½-inch instantaneous with variable nozzle, 1 Jumbo branch (to take 2–3-inch instantaneous hose) with 1½-inch nozzle, 1 long branch 3-inch instantaneous with 1¼-inch nozzle, 2 Ajax branches 2½-inch instantaneous with ⅞-inch nozzles, 2 dividing breechings 3 inch into 2–2½-inch instantaneous, 1 dividing breeching 2½ inch into 2–2½-inch instantaneous, 8 spare nozzles (4 1-inch, 2 ⅞-inch, and 2 ¾-inch), 3 nozzle spanners, 2 spanners for 2½-inch universal screw connections, 6 suction washers (fibre), 4 rubber washers 2½-inch instantaneous, 4 rubber washers 3-inch instantaneous, 2 goose-neck standpipes 2½-inch

instantaneous, 3 leather washers for standpipes, 1 toggle pin for hydrant box doors, 1 blank flange 2½-inch instantaneous, converter adaptors (see list of same), 2 skid chains, 2 driving chains.

Right Foot Locker.—2 hydrant keys, 2 crowbars, 1 toggle pin, 1 saw, 2 spades, 1 7-lb. axe, 1 14-lb. hammer, 11 hose clamps (4 leather and 7 canvas), 1 universal adaptor.

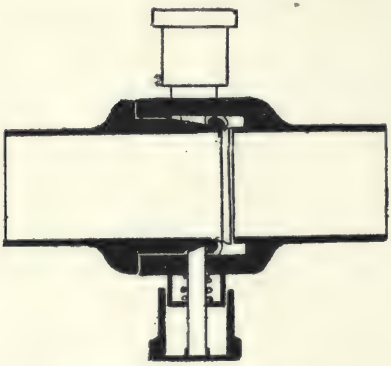
Under Driver's Seat.—2 Oldham electric hand-lamps, set of tools for engine, 1 box containing 2 Route and Order books, and 1 case of maps of district served.

Water Lights consist of cylinders 15 inches long × 5 inches diameter, containing 5 lb. calcium carbide, may be conveniently used for lighting up any ground, e.g., the top of a shaft, etc.

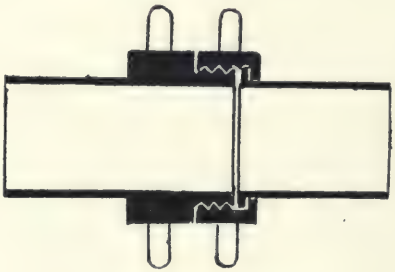
A 200-c.p. light, lasting for 4 hours, can be obtained by pulling off one of the strips, or a 400-c.p. light, lasting for 2½ hours, by pulling off the 2 strips which seal the holes. A single strip on the bottom of the cylinder is also torn off, and the whole placed in a bucket of water. A light is then applied to the apertures on the top where the strips were torn off. Care must be taken to see that the end with the two strips is uppermost. These water lights are extremely dangerous if not kept in a dry place, and after the strips have once been removed they are not to be stowed away in the cars or handled.

Swift Control Branch.—This branch is fitted with a device whereby a straight stream can be delivered as in the ordinary branch, or a spray can be delivered, or both together. The solid stream issues from the centre and a little in front of the circle described by the spray. With such a nozzle a person can enter a burning structure, driving the smoke or noxious vapours before him, overcoming the heat, wetting down large surfaces, and at the same time throwing a jet in front of him upon any point he may desire.

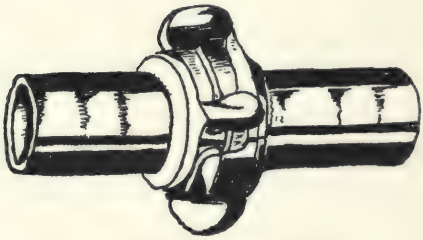
Converter Adaptors.—2½-inch instantaneous male to 1¼-inch instantaneous female, 1¼-inch branch with ¼-inch nozzle attached. Nunan and Stoves' coupling to 2½-inch screw female. Nunan and Stoves' coupling to 2½-inch screw male. Nunan and Stoves' coupling to 2½-inch instantaneous male. 2½-inch screw female



INSTANTANEOUS COUPLING.



"V" THREAD COUPLING.



NUNAN STOVE COUPLING.

FIG. 31.—TYPES OF FIRE HOSE COUPLINGS.

to 2½-inch instantaneous female. 2½-inch screw male to 2½-inch instantaneous male. 2 2½-inch instantaneous females to Nunan and Stove. (See Fig. 31).

Universal Adaptor.—A short piece of hose with piping to couple up to any connection. In this case the coupling is cut off the hose.

An excellent Central Rescue and Fire Station has been built at Chesterfield by the North Midland Coal Owners Rescue Stations Co., Ltd. (This is

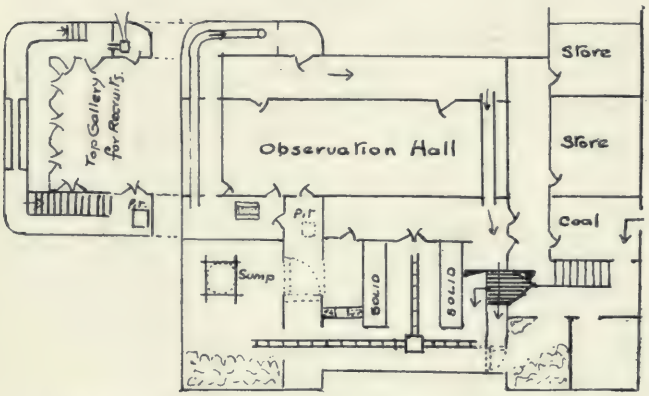


FIG. 32.—PLAN OF CHESTERFIELD TRAINING GALLERY.

(*Scale* 1 *inch* = 12 *feet.*)

fully described, with illustrations, in *Colliery Guardian* of February 27, 1920.)

Training Gallery.

The training gallery at this Station is probably the best of its kind which has yet been made.

Fig. 32 is a line drawing of it in ground plan.

A top gallery on the ground floor for recruits or beginners extends on three sides of the observation hall. A furnace supplies the poisonous fumes, and a Sirocco fan, 12 inches in diameter, and driven

by a 1½-horse-power motor, draws them through the gallery.

Emergency swing doors allow ready access in case of a man falling unconscious.

At one end of this top gallery is a little shaft or staple-pit, fitted with overhead pulley gear and a kibble, which connects it with an extensive underground excavation.

Here are to be found some of the ordinary features of a coal mine, e.g., ventilation doors, an air-crossing, stoppings, and a sump.

A sump (i.e., an excavation in the floor holding water) is useful for instructing men in the use of portable hand-pumps for dealing with underground fires.

There are facilities for varying the temperature of the air, and for reversing the air current.

A sloping roadway leading to the top of the " staple " pit is so made that its height and inclination can be varied. It thus affords varied conditions of practice for men wearing breathing apparatus.

Altogether this gallery is well designed for the efficient training of men in Mine Rescue and Fire Work.

Advantages of Central Rescue and Fire Stations.

A Central Rescue and Fire Station maintaining a resident brigade has several advantages over other systems of Rescue organization.

A higher standard of efficiency is attained. Life and property are saved, and stoppage of work at the attached collieries is avoided by the prompt and efficient action of the brigade. Colliery managers, whose duties are onerous, are spared the time and labour required for the training and maintenance of brigades. A smaller number of the men employed

at a colliery require to be trained, see page 10. As the men are trained for both Fire and Rescue Work, the cost of a separate Fire Brigade is saved.

The Rescue Appliances which have to be provided and maintained at one Central Rescue Station are much fewer and simpler than at a number of individual mines, and there is therefore less loss by depreciation.

The Insurance Premiums of the attached collieries are less by 5 to 10 per cent. owing to their having a call on an efficient fire brigade.

Rescue Organization in the U.S.A.

In the U.S.A. the areas of the coalfields are much more extensive than in the United Kingdom, the

Plan.

FIG. 33.—U.S.A. BUREAU OF MINES RESCUE CAR FOR RAILWAY

(*Scale* 1 *inch* = 16 *feet.*)

distances to be traversed are much greater, and the organization of Rescue Work and training is somewhat different.

This difference lies mainly in the utilization of railway Rescue Cars, which are really movable Rescue Stations, to supplement the fixed Stations.

The State of Illinois was the first to provide a Rescue service, which it did in 1910. This State covers an area of 56,650 square miles, with a population of about 70 persons per square mile. The area of England and Wales is 58,309 square miles, having an average population of 550 persons per square mile. In Illinois there are three Central

Rescue Stations, supplemented by three railway Rescue Cars. In England and Wales there are forty-three Rescue Stations.

These cars are used not only to take the permanent Rescue Brigades from the Central Stations to a mine on the occasion of a disaster, but also, when not thus engaged, they travel through the coalfield from colliery to colliery and train the local men in Rescue Work; and this is their most valuable function.

For this training work they carry a crew of six men, viz., two mining engineers (experienced in Rescue Work and capable instructors), a foreman miner, a cook, a clerk, and a surgeon.

The cars, made all of steel, see Fig. 33, provide comfortable living quarters for this crew. One end of the car is fitted up as a demonstration room, and here the equipment is carried. It comprises twelve sets of Self-contained Breathing Apparatus, safety lamps, electric lamps, first-aid supplies, fifteen 100-cubic feet cylinders of compressed oxygen, gas analysis apparatus, oxygen pump, four reviving apparatuses, one smoke helmet and respirators, a meter, breathing apparatus accessories and spares.

The daily routine of the crew when on duty with the car is as follows :—

7 a.m. to 7.10 a.m.	..	Physical drill.
7.30 a.m. to 8 a.m.	..	Two-mile walk.
8 a.m. to 8.30 a.m.	..	Breakfast.
8.30 a.m. to 12.30 p.m.	..	Instruction to miners and training in Rescue Work.
12.30 p.m. to 1.30 p.m.	..	Dinner
1.30 p.m. to 4.30 p.m.	..	Instruction to miners in First Aid.

4.30 p.m. to 5.30 p.m. .. Overhaul equipment.
5.30 p.m. to 6.30 p.m. .. Supper.

Five days of four hours a day is the usual period devoted to training in Rescue Work at each colliery, most of this training being given underground. Training in First Aid occupies a period of three hours a day for five days.

At each of the three Central Stations, besides the permanent brigade, there is accommodation for twelve to fifteen men in training at one time.

VIII

INSTANCES OF THE USEFUL EMPLOYMENT OF RESCUE BRIGADES.

The Durham and Northumberland Collieries Fire and Rescue Brigade has four Central Stations, to which are attached 331 collieries, employing about 176,000 persons, producing about 42,000,000 tons of coal yearly, and covering an area of about 750 square miles. These collieries include a considerable variety—deep shafts and shallow shafts, thick seams and thin seams, dusty and wet, fiery and non-fiery, old collieries and new collieries.

They may be taken as fairly typical of the whole country.

During last year there were thirty-six calls on the services of the Brigade. The attached collieries, of course, have the first claim on its services, but the Brigade is always ready to turn out to any call for its assistance to extinguish fires.

All the thirty-six calls were to fires—there was no explosion. The number of men turned out varied from six, when the fire was a small one, to twenty-four, when a big colliery heapstead with pulley frames and screening plant was ablaze.

Of the thirty-six calls, seventeen were to collieries, and nineteen to other places.

Of the seventeen colliery calls, only three were

to underground fires, and fourteen were to fires above ground.

Colliery Surface Fires.

Of the fourteen surface fires, besides the heapstead fire already mentioned, three fires were in engine houses, two in lamp cabins, two in woodwork near the pithead, one arose at a new coke yard from the gas escaping from an exhaust plant catching fire, and the remainder in various premises about the pithead.

At the heapstead fire, which was the most serious, there was fortunately an ample supply of water from the colliery pond, and the Brigade, on arrival with the motor pump, quickly got five branches of hose-pipe, delivering five strong jets of water, to bear on the fire. After working with these for a short time, it was decided to concentrate the full force of the motor pump through a 1½-inch jet (a Jumbo branch) on to the headgear and pulleys. The effect was very satisfactory, the fire being literally knocked out.

In his annual report for 1919 Mr. J. R. R. Wilson, H.M. Inspector of Mines for the Northern Division, referring to this fire, states: "The occurrence demonstrated the usefulness of the coalowners' combined Rescue and Fire Brigades, as it was owing to the speed with which the Brigade reached the premises, and the completeness of their equipment which prevented the place being gutted."

Of the nineteen calls to places other than collieries, a large proportion was to farms, where stacks or farm buildings had caught fire.

Underground Fires.

Of the three underground fires, one was in a

hauling-engine house, 300 yards inbye from the shaft. Fourteen brigademen were turned out. Two brigade hand-pumps were brought into use, and the fire was got under control in about an hour, little damage being done.

The two other underground fires occurred at the colliery where the heapstead had been on fire a few days previously, and no doubt were caused by it.

The first was very small in extent ; in the High Main seam, at a depth of 94 yards, in a drift between the downcast and upcast shafts. It was damped down with wet sand without much trouble. Two days later a fire was discovered in a small drift in coal, 3 feet by 4 feet, opening into the same shaft at a depth of 212 yards from the surface. The coal was burning for a distance of 6 yards along the side of this drift. Wet sand was used to smother and check it, but for its extinction it was necessary to get a supply of water from a hydrant on the surface. To save the time required for fixing a column of metal pipes (gas piping) in the shaft, it was decided to try canvas hose-pipe. This was carried out with entire success. The fear, of course, was that the hose might not be strong enough to stand the strain. Instantaneous hose, $2\frac{1}{2}$ inches diameter, was used. It was lashed with rope to the wooden buntons in the shaft at intervals of about 20 feet, so that its weight was carried by the buntons. A curved bearing was made to carry it over the edge of the shaft. The end of the hose next the fire was fitted on to a piece of iron piping perforated with holes. In all, about 222 yards of hose were hung down the side of the shaft.

The water was turned on slowly so as to avoid forming a head of water within the hose, which might have burst it.

Water was poured on to the fire for three days, by which time it was entirely extinguished, and then all the material which had been on fire was dug out.

In these cases of underground fire the ventilating fan was stopped. It may be useful to know that a good current of air was found to be passing round the mine several hours after the fan had been stopped. In one instance, after about twelve hours stoppage of the fan, a current of over 35,000 cubic feet of air per minute was passing in the fan drift.

Explosions.

Fortunately colliery explosions are becoming rare occurrences, certainly more rare than colliery fires, but at the few explosions which have occurred within recent years Rescue Brigades have proved their value.

Minnie Pit, North Staffs.

The most recent instance, which has been fully investigated and reported on, is the explosion which occurred at the Minnie Pit of the Podmore Hall Colliery, North Staffordshire, on January 12, 1918. This explosion caused the loss of 155 lives. The subsequent inquiry led to the conclusion that 144 of these deaths were due to Carbon Monoxide poisoning, and eleven to violence *plus* Carbon Monoxide poisoning. Ninety-three persons got out alive, the number employed underground at the time of the explosion being 248. The seam where the explosion occurred gave off firedamp freely, and was liable also to spontaneous combustion or gob fires.

This made the recovery of the mine particularly dangerous and difficult.

The explosion, however, was not due to gob fire.

The evidence, as fully set out in the Report of

the Chief Inspector, Mr. W. Walker, dated May 31, 1920, points to the cause of ignition being either a defective safety lamp, or sparks produced by falling stone.

After the explosion, one of the first steps taken by the manager was to ring up the Central Rescue Station at Stoke-on-Trent and ask for Rescue Apparatus and teams to be sent immediately.

A fully-equipped Brigade soon descended the downcast shaft, which was not affected by the explosion, with instructions to travel as far as it could in the direction of the workings where the explosion had occurred. On their return they reported the existence of large falls of stone at certain points, and of smoke coming out of the district of the mine which had been devastated by the explosion. This report was received about three hours after the occurrence of the explosion, and led to the decision to seal off this district temporarily, as it seemed probable that fire had broken out in it. The second Brigade that went down on the day of the explosion took a sample of the air in the main return, a subsequent analysis of which showed 3·24 per cent. of Carbon Dioxide, 1·03 per cent. of Carbon Monoxide, 15·03 per cent. of Oxygen, but no Methane (CH_4).

A bird taken to the same place died at once.

Rescue Brigades continued to attempt to enter into this devastated area of workings in advance of the air, till, on the afternoon of the day following the explosion, it was decided to carry forward the air with them. Better progress was then made. It was on the morning of the following day, two days after the explosion, that Hugh Doorbar lost his life whilst wearing Breathing Apparatus in an irrespirable atmosphere.

On January 16, four days after the explosion, it was realized that the exploration of the main portion of the devastated workings, where ninety-eight bodies were lying, was going to be a long and anxious matter, and would in all probability have to be done by means of Rescue Brigades wearing Self-contained Breathing Apparatus.

A consultative Committee of Mining Engineers was appointed to consider with the owners and H.M. Inspectors the best procedure.

On February 5 it was agreed to commence opening the district in question.

The finding of gob stink, indicating the presence of fire, and the risk of a further explosion, delayed operations, and finally led to their total suspension for some time.

Stoppings were built to seal off the district and exclude all air. Samples of the atmosphere behind these stoppings were taken from time to time.

By March 27 the enclosed atmosphere was found to contain less than 5 per cent. of Oxygen at the various stoppings, and the gob stink had disappeared.

Still the admission of air might easily cause fresh fire in any heated mass, and it was evident that the work of exploring the sealed-off district, and recovering the bodies, could not be done without risk to the Rescue Teams.

The Committee had to take into account the fact, (see Inspector's Report) that the common experience in North Staffordshire is, that attempts to re-open districts once closed against gob fire lead to a recurrence, and only in extremely rare cases, and after the lapse of considerable time, have such attempts been successful.

It was finally decided that " Exploration in sec-

tions after Rescue Teams have sealed the forward areas by advanced stoppings is the only possible method."

A scheme for carrying this out, which had been submitted by Mr. Saint, H.M. Senior Inspector of Mines, was approved.

This scheme suggested, *inter alia*, that men wearing Rescue Apparatus should enter the road leading into the sealed-off district, in order to ascertain the best position in which to build advance stoppings in the intake and return, and afterwards should be employed in conveying materials, and building wood stoppings laid in and sealed with cement.

Also that each section of roadway should be explored, ventilated, and repaired, before another section is opened; that after the exploration of a district has been completed, it should be sealed off, and that a good line of retreat should be maintained at all times.

In his report, the Chief Inspector, Mr. Walker, states that the work was done in stages by means of Rescue Brigades wearing Proto Self-contained Breathing Apparatus, the roads and workings in front being kept flooded with firedamp, so as to avoid any risk from spontaneous combustion. The work was started on July 18, 1918, and four Brigades were engaged for more than twelve months. Thirty-four stoppings were built in an atmosphere devoid of Oxygen, and the seam was opened up, step by step, until finally the last body was brought out on August 19, 1919.

This example of Mine Rescue Work demonstrates both the value of Breathing Apparatus with men trained in the use of it, and also, by the unfortunate death of Hugh Doorbar, the vital necessity of the greatest care in the preliminary examination of the

Apparatus when putting it on, to see that it is in perfect working order.

More recently there has been another lamentable instance of the danger to which men wearing Breathing Apparatus underground in a poisonous atmosphere are exposed, and of the need of care and caution.

At an underground fire in the Newliston Shale mine in Scotland, in 1919, three members of a Rescue Brigade wearing Proto Apparatus lost their lives.

In his annual report Mr. H. Walker, H.M. Inspector of Mines, referring to this accident, states that it was due in the first place to a lack of strict discipline, which he describes at some length. The actual cause of death in one case was that, when climbing uphill on the very slippery floor of the shale mine, the man slipped, and in falling his nose-clip came off. "The same thing appears to have happened to two others." But a subsequent examination by Dr. Briggs of the Apparatus worn by them, led him to the conclusion that "if the Apparatus were used in air fouled by white damp in the condition in which it was when handed to him, the death of the two men was due to poisoning by Carbon Monoxide drawn in through leaks in the breathing circuit of the Apparatus."

It should be noticed that these accidents with the Proto Apparatus are not due to inherent defects in the construction of the Apparatus, but to carelessness in the use of it, and to want of adequate testing before use. Being more generally used than any other Breathing Apparatus, the Proto figures most prominently in these reports of accidents.

North Staffordshire affords another instance of the value of Rescue Brigades trained in the use of

Breathing Apparatus in recovering a mine after an explosion.

Norton Colliery, North Staffordshire.

This was at Norton Colliery, where an explosion occurred on February 24, 1912. Fortunately, it was a Saturday afternoon, when the pit was idle and only one life was lost, but the explosion was a great one, causing much damage to the mine.

Here again the liability of the seams to spontaneous combustion and the existence of gob fires constituted the great danger and difficulty in the work of recovery.

Within three hours after the explosion, six men of the local Rescue Brigade, wearing Proto Breathing Apparatus, descended one of the three shafts and made an examination, lasting for twenty-five minutes. A second team descended soon afterwards, and from their reports it was judged that there was fire in the workings. The ventilating fan was therefore stopped, and all the shafts and the fan chimney were sealed, in order to cut off all circulation of air through the mine, and thus extinguish the fire. Samples of air from the sealed shafts were taken daily and analysed, and on March 2 one of the three shafts was re-opened, and a party wearing Breathing Apparatus went down, 386 yards in depth.

The investigation enabled the position of the fire to be located. It was in a district of workings reached by a pair of " dip " headings or slopes. In order to stop the circulation of air and extinguish the fire in this district, stoppings were built in each of these slopes at their top. This work was completed by March 9, and the district remained sealed till April 2.

These slope roads had been destroyed by the

explosion, and the work of recovering them was now begun.

Three teams of five men each were chosen, men who had gone through a course of training at the Stoke Rescue Station. The Proto Apparatus was used.

Their work consisted of clearing falls of stone, setting timber, laying railway, replacing doors and air crossings, and building new stoppings. It occupied 120 days, or about four months, and during this period they actually lived on the Oxygen supplied by their Breathing Apparatus for 360 hours.

They worked for periods of 1½ hours at a time in the irrespirable atmosphere, and in a temperature which reached 75° Fahr., and then for one and a half hours they remained in attendance outside the stoppings, with their Apparatus on, but uncoupled, ready for any emergency.

During their daily shift each team did three hours actual work in the irrespirable atmosphere in 1½ hours turns, and three hours in attendance outside the stoppings.

When they had been engaged in the work for about two months, they were medically examined by Dr. J. S. Haldane. He reported that though the strain of the work was evidently considerable, he " could find no indication of any physical deterioration, except what a short holiday would very rapidly make up for." [1]

Lodge Mill Colliery, Huddersfield.

The first recorded case of a life saved by the use of Self-contained Breathing Apparatus in a

[1] See paper by J. R. L. Allott, " The Re-opening of Norton Colliery with Self-contained Breathing Apparatus after an Explosion," *Trans. Inst. Mining Engineers*, vol. xlv.

coal mine in this country occurred on January 28, 1913, at Lodge Mill Colliery, a small colliery about four miles from Huddersfield. Four men employed during the night shift in removing rails in a disused part of the workings were overcome by gas. Numerous and continued efforts were made to reach them and bring them out, but the suffocating nature of the atmosphere rendered this impossible.

A call for help was sent to the Altofts Rescue Station, and six trained men of the Altofts Rescue Brigade started at once. Owing, however, to the breakdown of a motor, it was not till some nine hours after the men had been overcome by the gas that three of the members of the Rescue Brigade arrived at the colliery.

The place where the men were lying was about a mile from the shaft in a thin seam, and the roads were not more than three feet high on an average.

The rescuers, wearing the WEG Apparatus, but carrying their headpieces, were run inbye, lying flat on low trams until they reached a point about eighty yards from the place. Then, donning the full equipment and carrying electric lamps, they went forward and found the men lying close to the face of a road, little more than two feet high.

They succeeded in bringing out to the fresh air all the four men, using low trams for this purpose, and making four journeys through the suffocating gas. Two of the four men were still breathing, though in a very critical state. One recovered completely in a few days, but the other died in the Huddersfield Infirmary. The other two, who were older men, were dead when found.[1]

[1] See paper by W. D. Lloyd, "An Account of the Use of Rescue Apparatus at Lodge Mill Colliery, Huddersfield," *Trans. Inst. Mining Engineers*, vol. xlvi.

This was seven years ago, when Rescue Organization was in its infancy. Now, with improved appliances, and better organization, there can be little doubt that in such an event the lives of all four men would be saved.

These instances suffice to show the scope there is for the work of Rescue Brigades.

Subsequent experience has fully verified some observations contained in the First Report (1907) of the Royal Commission on Mines, which was appointed in the previous year. " Apart from actual Rescue Work, Breathing Appliances may be of great service in making it possible to deal with underground fires more safely and effectively than would otherwise be the case."

" We do not think that Breathing Appliances can play more than a subsidiary part in Rescue operations after an explosion, but this part may sometimes be of considerable importance."

The following statement, which is taken from the handbook on " Rescue and Recovery Operations in Mines after Fire and Explosions," issued by the Bureau of Mines, U.S.A., deserves attention : " When travelling in afterdamp or other noxious gases the rescue crew should observe every known precaution to insure their safety. Each crew should be composed of at least five men, including the captain, and the members of the crew should not become separated. If any member complains of feeling ill or is observed to be staggering or breathing unnaturally, the entire crew should immediately return to fresh air. With the types of breathing apparatus now in service the maximum straightaway, unobstructed course should not exceed 5,000 feet, with a reserve crew at the fresh-air base."

IX

A SELECTION OF QUESTIONS

Selection of Questions.

AMONGST the subjects with which a colliery manager nowadays should be well acquainted, Rescue Work must be included, and in the examinations for certificates of competency, as laid down in Government Regulations, some questions on Rescue Work are always asked.

A selection of these questions during recent years is appended. The attentive reader of this book will be able to answer them.

(1) With what type of Rescue Apparatus are you familiar ? Sketch and describe the same. (1912.)

(2) How many Rescue men would you require, and how would you organize them for repairing a stopping 100 yards distant from fresh air, only two men being able to actually work at the stopping at one time, and no material having to be carried to them ? The completion of the work to occupy six hours. (1912.)

(3) Describe the organization of a Rescue Brigade, and the course of training necessary to qualify for the actual work of rescue or exploration. (1913.)

(4) Give a simple outline sketch of a type of Rescue Apparatus with which you are familiar, and state some of the precautions to be observed by a person using the same. (1913.)

(5) Describe with sketch any type of Rescue Apparatus with which you are familiar, and explain upon what

principles its safety depends, and what defects or misuse would render it unsafe. (1912.)

(6) After an explosion how would you organize parties of Rescue men to search 300 yards of coal face, for survivors or victims? All the work to be conducted from a road at one end of the face. (1913.)

(7) Discuss the use of Rescue Apparatus underground in an atmosphere of dense smoke and high temperature after a fire. What type of apparatus would you prefer, and what special care should be exercised under the circumstances? (1915.)

(8) Sketch and describe a type of Rescue Apparatus, and state particularly what risks and dangers are to be guarded against in its use. (1915.)

(9) After an explosion, when sending a Rescue party into the mine from the surface, state how the party should be constituted and equipped for the purpose of ascertaining the cause of the explosion. (1914.)

(10) In the event of a serious outbreak of fire at the screens near the top of the downcast shaft during working hours, what steps would you take for the safety and rescue of the men underground? (1914.)

(11) Rescue Apparatus. 1. How is the supply of Oxygen regulated and what is the necessary rate of supply? 2. What is the purpose of the by-pass valve? 3. What is the purpose of the breathing bag?
Alternative question. Describe the liquid air apparatus. (1916.)

(12) A Rescue team wearing Apparatus is working at some distance from the base, when one of the party shows signs of exhaustion. What is the probable cause of this exhaustion, and what should be done to restore him and get him out? (1916.)

(13) Describe fully the equipment and organization you would establish at a large colliery for dealing with outbreaks of fire. (1917.)

(14) When using Rescue Apparatus, how long may the wearers be away from the base, how far may they go, how far should they travel, and how much work can they do, compared with men under ordinary circumstances and not wearing Apparatus? (1917.)

(15) In a Self-contained Breathing Apparatus, how is the Oxygen supply assured, and excess of CO_2 prevented?

What would you do to detect and guard against these matters? Illustrate your answer by sketches. (1918.)

(16) Describe the course of training necessary to qualify a man to undertake Rescue Work with Apparatus. (1918.)

(17) Give a list of risks avoidable and unavoidable that are incurred by men using Rescue Apparatus in irrespirable atmospheres underground. (1919.)

(18) In the case of a Rescue Team working in an atmosphere obscured by smoke, how would the members of a team communicate with each other? (1920.)

(19) Where does spontaneous combustion most frequently occur underground, and what is generally the cause of it? (1920.)

(20) Sketch a type of smoke helmet (hot Oxygen or liquid air apparatus). What are its limitations in practical use? (1920.)

(21) How many men should be trained in Rescue Work in a colliery employing 1,000 persons underground, and after training, how should they be kept in practice and ready for emergency? (1920.)

(22) Make a sketch plan, and describe the general equipment, of the room to be provided at every mine for Rescue and Aid purposes. (1920.)

APPENDIX I

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COAL MINES ACT, 1911.

RESCUE WORK.

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I. Introduction.

This memorandum, containing all the regulations in force with regard to rescue work, the schemes of training approved by the Home Office, and other matter, is issued for the convenience of those connected with the organization and control of rescue work.

The original Regulations, which were made in 1913 under Section 86 of the Coal Mines Act, 1911, were amended in the following year by the General Regulations of the 19th May, 1914, and have now been further amended and extended by the General Regulations of 30th July, 1920, Part III., Nos. 11 to 37. These latter Regulations were based on the published reports[1] of the Research Committee appointed by the Advisory Council for Scientific and Industrial Research in May 1917, to investigate the types of breathing apparatus used in coal mines, of which Committee Mr. W. Walker, C.B.E., H.M. Chief Inspector of Mines, was the Chairman.

The new Regulations are divided into three parts (*a*), (*b*), and (*c*), dealing respectively with the design and testing of apparatus, the selection and training of rescue corps and rescue brigades, and miscellaneous matters, and three Schedules prescribing respectively a code of ventilation signs, a code of signals, and rules for rescue work which are to be adopted in all cases. After

[1] First and Second Reports of the Mine Rescue Apparatus Research Committee.

1st January, 1922, or such later date as the Chief Inspector of Mines may allow, only apparatus of a type which has been approved by the Secretary of State must be used; and apparatus in use is to be thoroughly tested from time to time. Defective apparatus is a source of great danger to the wearer and a number of lives have been lost from this cause. A proper room for rescue and aid purposes is to be provided at every mine. Practical experience in a mine is made a condition of selection *in the future* for employment in a rescue corps or brigade. The provision in the previous regulations that members of a rescue corps must be continuously employed and in constant residence at the station has been modified to this extent that members of a rescue corps may, with the approval of the Secretary of State and subject to such conditions as he may lay down, be engaged in mines in the immediate neighbourhood of the station. Power is given to the Secretary of State to require any mine to become a member of a Central Station if the mine is situated within 10 miles of it, and the controlling authority of the station is prepared to admit the mine on reasonable terms. The rescue regulations are now extended to mines of oil shale which were previously exempt.

The schemes of training approved by the Secretary of State in January 1915, under the General Regulations of 19th May, 1914, and 10th July, 1913, remain in force. The schemes were made as elastic as possible and they appear to have satisfied all requirements. No applications for the approval of the Secretary of State to any variations have been received.

HOME OFFICE,
WHITEHALL,
September, 1920.

II. General Regulations of 10th July, 1913.

In pursuance of Section 86 of the Coal Mines Act, 1911, I hereby make the following Regulations, . . .

* * * * * *

(138) The following Regulations shall apply to all mines in which coal is worked,[1] provided, however, that the Secretary of State may, if he thinks fit, exempt from the Regulations any mine at which the total number of underground employees is less than 100 if the mine is so situated that in the opinion of the Secretary of State the organization of a Central Rescue Station from which it could be served is impracticable.

(139) No person, unless authorized by the manager or official appointed by the manager for the purpose, or, in the absence of the manager or such official, by the principal official of the mine present at the surface, shall be allowed to enter a mine after an explosion of fire-damp or coal-dust, or after the occurrence of a fire, for the purpose of engaging in rescue work.

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[1] The regulations are extended to oil shale mines as from 1st January, 1921. See No. 27 of the Regulations of 30th July, 1920, see p. 12.

(140)—(*a*) There shall be organized and maintained at every mine, as soon as is reasonably practicable, competent rescue brigades on the following scale :—

Where the number of underground employees is 250 or less	1 brigade
Where the number of underground employees is more than 250 but not more than 700	2 brigades
Where the number of underground employees is more than 700 but not more than 1,000	3 brigades
Where the number of underground employees is more than 1,000	4 brigades

But the owner, agent or manager of a mine, at which the total number of underground employees is less than 100, shall be deemed to have complied with this provision if he has acquired the privilege of calling for a brigade from a Central Rescue Station.

A group of mines belonging to the same owner, of which all the shafts or exits for the time being in use in working the mines lie within a circle having a radius of two miles shall, for the purpose of ascertaining the number of brigades required, be treated as one mine.

(*b*) A rescue brigade shall consist of not less than five persons employed at the mine, carefully selected on account of their knowledge of underground work, coolness and powers of endurance, and certified to be medically fit, a majority of whom shall be trained in First Aid and shall hold a Certificate of the St. John Ambulance Association or the St. Andrew's Association or other Society or body [1] approved by the Secretary of State.

(*c*) There shall be selected from the ranks of each rescue brigade one person or leader who shall act as captain of the brigade.

(*d*) A brigade shall not be deemed competent unless (i) it undergoes a course of training approved [2] by the Secretary of State ; (ii) after the preliminary course of training it undergoes in every quarter at least one day's practice with breathing apparatus which practice shall at least twice in the year take place at the mine ; (iii) the members of the brigade shall have received instruction in the reading of mine plans, in the use and construction of breathing apparatus, in the properties and detection of poisonous or inflammable gases, and in the various appliances used in connection with mine rescue and recovery work.

(*e*) Arrangements shall be made at every mine for summoning members of rescue brigades immediately their services are required.

(141) If it can clearly be proved that the necessary number of persons employed underground at a mine will not consent to form a brigade or brigades, or having offered their services fail to be trained or maintain their training, the owner, agent or manager of the mine shall not be liable to any penalty provided

[1] For List of Approved Societies, see Part IX.

[2] For Scheme approved by the Secretary of State, see Part V.

first that he has endeavoured to the best of his ability to constitute the requisite brigade or brigades, and has afforded every opportunity to the persons employed at the mine to undergo the necessary training, and secondly that he has made a *bonâ fide* attempt to arrange for the supply from a Central Rescue Station of such rescue brigades as he is unable to provide at his mine.

(142)—(*a*) There shall be provided and maintained at every mine suits of portable breathing apparatus in the proportion of two suits to each brigade required by Regulation 140 (*a*). The apparatus must be capable of enabling the wearer to remain for at least one hour in an irrespirable atmosphere, and must be kept ready for immediate use. The apparatus must be housed in suitable receptacles in a dry and cool room.

The owner, agent or manager of a mine shall be deemed to have complied with this requirement if he has acquired the privilege of calling for such of these appliances as he may not possess from a Central Rescue Station, always provided that the Central Rescue Station is situated within a radius of 10 miles from the mine and is in telephonic communication with the mine.

(*b*) There shall be kept at every mine tracings of the workings of the mine up to a date not more than three months previously, showing the ventilation and all principal doors, stoppings and air crossings, regulators and telephone stations, and distinguishing the intake air by a different colour from the return air, which tracings shall be in a suitable form for use by the brigades.

(*c*) There shall also be provided and maintained at every mine which maintains a rescue brigade or brigades—

(i) Two or more small birds or mice for testing for carbon mon-oxide.
(ii) Two electric hand-lamps for each brigade, ready for immediate use and capable of giving light for at least four hours.
(iii) One oxygen reviving apparatus.
(iv) A safety lamp for each member of the rescue brigades for testing for fire-damp.
(v) An ambulance box provided by the St. John Ambulance Association or similar box, together with antiseptic solution and fresh drinking water.

(143) There shall be kept and maintained in every Central Rescue Station not less than 15 complete suits of breathing apparatus, with means of supplying sufficient oxygen or liquid air to enable such apparatus to be constantly used for two days and of charging such apparatus; and

20 electric hand-lamps;
4 oxygen reviving apparatus;
An ambulance box or boxes, provided by the St. John Ambulance Association, or similar boxes, together with antiseptic solution and fresh drinking water;
Cages of birds.
A motor-car shall be kept in constant readiness.

(144) Every Central Rescue Station shall be placed under the immediate control of a competent person conversant with the use of the appliances.

(145) There shall be adopted at every mine by the owner, agent or manager such rules for the conduct and guidance of persons employed in rescue work in or about the mine as may appear best calculated for the carrying out of rescue operations, and the rescue brigade or brigades, if any, maintained at the mine shall be thoroughly instructed in such rules.

(146) "Central Rescue Station" means a station established to serve several collieries.

* * * * * * * * * * *

R. McKENNA,
One of His Majesty's Principal Secretaries of State.

HOME OFFICE,
WHITEHALL,
10*th July*, 1913.

III. General Regulations of 19th May, 1914.

In pursuance of Sections 85 and 86 of the Coal Mines Act, 1911, I hereby make the following regulations amending the General Regulations made under the said Act and dated 10th July, 1913 :—

Special Provisions for Mines served by a Central Rescue Corps.

1. Nos. 140, 141 and 142 of the General Regulations abovementioned shall not apply to any mine which is served by a Central Rescue Station maintaining a permanent rescue corps and which is situated within a radius of 10 miles from the station and is in telephonic communication with it, subject to the following conditions :—

(*a*) The rescue corps at the Central Station shall consist of not less than six men, or if the total number of underground employees at all the mines served by the station in pursuance of this Regulation exceeds 15,000, eight men.

The members of the corps shall be carefully selected on the ground of their coolness, powers of endurance and general suitability for the work, and shall be medically certified to be fit for the work ; and they shall hold a certificate of proficiency in first aid from a society or body [1] approved by the Secretary of State.

They shall be continuously employed and in constant residence at the station.[2]

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[1] For List of Societies approved by the Secretary of State, see Part IX.

[2] The following words are now added here by the Regulations of 30th July, 1920:—"Provided that if the Secretary of State so approves, and subject to such conditions as he may lay down, members of the rescue corps may, instead of being continuously employed at the station, be engaged in mines in the immediate neighbourhood of the station."

The corps shall be thoroughly trained in the use of breathing apparatus and in rescue work in accordance with a scheme approved by the Secretary of State, and shall be constantly kept in a highly efficient state.

One or more members shall be appointed to act as leaders.

(*b*) One or more persons employed at the mine for the time being shall be selected for the purpose of acting with the rescue corps from the Central Station when summoned, as follows :—

If the total number of underground employees is not less than 100 nor more than 250	Not less than 1 person.
If the total number of underground employees is more than 250 but not more than 1,000	Not less than 3 persons.
If the total number of underground employees is more than 1,000	Not less than 5 persons.

They shall be thoroughly trained, and shall from time to time undergo practices, at the Central Station, in the use of breathing apparatus and in rescue work in accordance with a scheme approved[1] by the Secretary of State.

They shall be carefully selected on account of their knowledge of the mine, coolness and powers of endurance, and shall be medically certified to be fit for the work, and shall hold a certificate of proficiency in first aid as above-mentioned.

Subject to the limit of number specified above, so far as reasonably practicable, at least one shall be selected from each shift.

Arrangements shall be made for summoning such persons immediately their services are required.

No breach of condition (*b*) shall be deemed to have arisen in consequence of failure to maintain at the mine the full number of trained men in accordance with the foregoing provisions if the owner, agent or manager of the mine satisfies the Inspector of the Division that he had made every effort to comply with those provisions and that the failure was due to causes over which he had no control.

(*c*) There shall be kept at every mine tracings of the workings of the mine up to a date not more than three months previously, showing the ventilation and all principal doors, stoppings and air crossings, regulators, and telephone stations, and distinguishing the intake air by a different colour from the return air, which tracings shall be in a suitable form for use by the corps.

(*d*) There shall be provided and maintained at the mine—

(i) Two complete suits of breathing apparatus or two smoke helmets (that is, appliances for supplying fresh air to the user by means of a pipe and bellows), or

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[1] For Scheme approved by the Secretary of State, see Part V.

one of each, in an efficient state and constantly ready for immediate use.

(ii) Two or more small birds or mice for testing for carbon mon-oxide.

(iii) One electric hand-lamp and one safety lamp, for testing for fire-damp, for each person trained in pursuance of condition (*b*) above.

(iv) One oxygen reviving apparatus.

Definition of "breathing apparatus."

2. For the purpose of the foregoing Regulation and of Part IV of the General Regulations above-mentioned, breathing apparatus means an apparatus of such a character that the wearer carries with him all the means for respiration in an irrespirable atmosphere, and is not dependent for them, while in such an atmosphere, on any other person or persons.

R. McKENNA,
One of His Majesty's Principal Secretaries of State.

WHITEHALL,
19*th May*, 1914.

IV. General Regulations of 30th July, 1920.

In pursuance of Section 86 of the Coal Mines Act, 1911, I hereby make the following Regulations, . . .

* * * * * *

PART III.—RESCUE.

(a) *Design and Testing of Apparatus.*

11. The breathing apparatus provided at a rescue station or mine in pursuance of the General Regulations of the 10th July, 1913, and 19th May, 1914, with regard to rescue work (hereinafter referred to as the existing Regulations) shall be of a type for the time being approved[1] by the Secretary of State, and no other breathing apparatus shall be used at any station or mine, except that any breathing apparatus at present in use may, with the consent of the Chief Inspector of Mines, be continued in use until the 1st January, 1922, or until such later time as apparatus of the approved type is obtainable in sufficient numbers.

12. In every breathing apparatus which is arranged so as to give a uniform oxygen delivery the reducing valve shall be so adjusted as to supply not less than two litres of oxygen per minute.

13. The oxygen in every cylinder supplied for use in connection with breathing apparatus shall be analysed before being used in a breathing apparatus, and if the oxygen is found to contain more than 2 per cent. of impurities, it shall not be used in any work

[1] A memorandum on the Test of Rescue Apparatus can be obtained from H.M. Stationery Office, price 2d. net.

or practice below ground, or in any practice above ground where the person wearing the apparatus is liable to be out of sight of the instructor. A record of the results of every analysis shall be kept in a book at the station or mine, as the case may be.

14. Every breathing apparatus shall on each occasion before being used below ground or in an irrespirable atmosphere in any practice be tested for leakage in the prescribed manner.[1]

15. Every breathing apparatus shall be thoroughly tested at least once a month in the prescribed manner[2] and a record of the results of the test shall be kept in a book at the station or mine, as the case may be.

16. If the Chief Inspector of Mines or the Inspector of Mines for the Division so requires, any breathing apparatus in use at a station or a mine shall be retested in the prescribed manner.[2]

17. Flow meters in use at a station or a mine shall be tested for accuracy at least once in every six months, and a record of the results of the tests shall be kept in a book at the station or mine, as the case may be.

(b) *Additional provisions as to selection and training of Rescue Corps and Rescue Brigades.*

18. No person shall be employed in a rescue corps or in a rescue brigade, and no person shall be selected at a mine for the purpose of acting with a rescue corps, unless he has passed the prescribed physical and medical test,[3] or if the superintendent of the rescue station or the captain of the brigade considers him unsuitable for rescue work with breathing apparatus, and (in the case of men hereafter selected) unless he has had practical experience in a mine.

19. Every rescue corps shall, after the completion of its training, undergo at least six practices underground in mines with breathing apparatus every year, and at least one such practice in every quarter.

20. There shall be appointed at every station a sufficient number of persons competent to train a rescue corps or rescue brigade, as the case may be, and to take charge of the station, of whom at least one shall always be in attendance, and the number shall, in no case, be less than the number specified in the following scale :—

(i) At stations maintaining a permanent rescue corps.—If the total number of persons employed underground at the mines served by the station does not exceed 15,000, two ; if the number exceeds 15,000, three.

(ii) At stations not maintaining a permanent rescue corps.—If the total number of brigades required to be provided at the mines served by the station does not exceed 50, two ; does not exceed 100, three ; exceeds 100, four.

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[1] For prescribed Test for Leakage, see Part VII.
[2] For prescribed Test for Breathing Apparatus, see Part VIII.
[3] For prescribed Physical and Medical Test, see Part VIII.

(c) *Miscellaneous Provisions.*

21. In the mine tracings required to be kept at the mine by the existing Regulations, the signs used shall be those specified in the First Schedule to this Part of these Regulations.

22. The code of signals used in rescue operations shall be the uniform code specified in the Second Schedule to this Part of these Regulations.

23. The rules for the conduct and guidance of persons employed in rescue work required by the existing Regulations to be adopted at every mine shall embody the uniform code of rules contained in the Third Schedule to this Part of these Regulations.

24. At every mine to which the existing Regulations apply there shall be a room provided and maintained exclusively for rescue and aid purposes. The room (*a*) shall be situated on the surface conveniently near the entrance of the mine and shall be distinguished by a large red cross on the door; (*b*) shall have a floor space of not less than 100 square feet and shall be provided with ample means of natural and artificial lighting and heating with a strong table and sufficient lockers, drawers and shelves for storing the articles required to be provided by the existing Regulations, and with a plentiful supply of drinking water and water for washing; (*c*) shall be placed under the charge of a person appointed in writing by the manager, who shall hold a certificate of proficiency in first aid from a society or body approved [1] by the Secretary of State, and shall also always be readily available during working hours and shall be responsible for maintaining the room and the fittings and appliances thereof in good order, and for attending to the needs and comfort of any rescue team or rescue brigade engaged in practices or work at the mine.

25. No. 1 of the General Regulations of the 19th May, 1914, shall be modified as follows:—After the sentence "They shall be continuously employed and in constant residence at the station" there shall be inserted the following:—"Provided that if the Secretary of State so approves, and subject to such conditions as he may lay down, members of the rescue corps may, instead of being continuously employed at the station, be engaged in mines in the immediate neighbourhood of the station."

26. Where a mine is situated within 10 miles of a Central Rescue Station and the Secretary of State is satisfied that the authority controlling the station is prepared to admit the mine to membership of the station on reasonable terms, he may require that the mine become a member of that station.

27. The existing Regulations and these Regulations relating to rescue shall, on and after 1st January, 1921, extend to every mine of oil shale, provided that the Inspector of the Division may, subject to such conditions as he thinks fit, allow any mine such extension of time as shall appear to him to be reasonably required in order to enable the mine to make the necessary arrangements.

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[1] For List of Societies approved by the Secretary of State, see Part IX.

First Schedule.

CODE OF VENTILATION SIGNS.

Brick, Stone, or Concrete Stoppings, explosion proof (*General Regulation* 91) .. ..

Brick, Stone, or Concrete Stoppings other than the above .. ..

Fire Dams or Seals .. .. ..

Doors .. ..

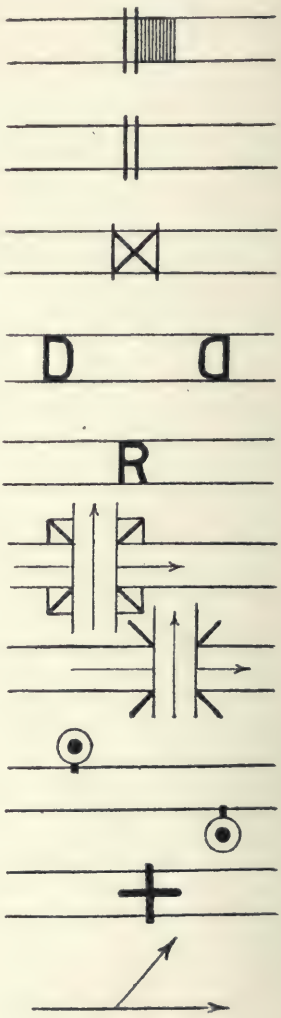
Regulators .. ..

Air Crossings, explosion proof (*Section* 42 (3), *C.M.A.*, 1911) ..

Air Crossings other than the above..

Telephones .. ..

Underground Ambulance Station (*in red*) .. ..



Direction of Air Current ——————>

Intake Airways—Blue. Return Airways—Red.

Second Schedule.

CODE OF SIGNALS.

Electrical Signalling.	Signalling between Members of a Brigade.	Signal.
"Distress" or "Help wanted"	"Distress" or "Help wanted"	ONE ring or ONE hoot
(*If* NO ANSWER *is given to a call, "Distress" is to be understood.*)		
"Not understood" or "Repeat the message"	"Halt"	TWO rings or TWO hoots
"No"	"Retire"	THREE rings or THREE hoots
"Yes," or "All right," or "All's well"	"Advance" ..	FOUR rings or FOUR hoots
To "ring up" or to "ring off"	To call attention ..	FIVE rings or FIVE hoots

Acknowledgment of Signal to be given by replying the Signal acknowledged.

Third Schedule.

UNIFORM CODE OF RULES FOR THE CONDUCT AND GUIDANCE OF PERSONS EMPLOYED IN RESCUE WORK.

MANAGER OR PRINCIPAL OFFICIAL FOR THE TIME BEING AT THE SURFACE OF THE MINE.

1. On receiving information of any occurrence likely to require the service of a rescue corps or brigade, the following steps shall be taken by the Manager, or, in his absence, by the principal official present at the surface :—

(*a*) Telephone to the Central Rescue Station. Inform the Instructor of the character of the occurrence. State whether assistance will be needed from rescue brigades other than the permanent station corps or the brigades attached to the mine ;
(*b*) Summon the trained men attached to the mine ;
(*c*) Telephone for medical assistance ;
(*d*) Telephone to the Inspector of Mines and the local offices of the Miners' Union and the Firemen's, Examiners' or Deputies' Association ;
(*e*) If necessary, communicate with the police station.

2. No person shall be allowed to enter the mine or the part of the mine which is unsafe for the purpose of engaging in rescue operations unless authorized by the Manager, or, in his absence, by the principal official of the mine present at the surface; and, during the progress of such operations, a person or persons shall be stationed at the entrance of the mine, and required to keep a written record of all persons entering and leaving the mine. Only men trained with the apparatus shall be permitted to enter the mine for the purpose of using breathing apparatus.

3. Prior to sending a brigade underground clear instructions shall be given to the leader of the brigade as to where it shall go and what it shall attempt. Unless the leader is personally thoroughly familiar with the roadways in question, the route shall be marked on a tracing, which the leader shall take with him into the mine.

4. A qualified medical man shall be in attendance at the mine wherever rescue parties are at work, unless in the opinion of the Manager and of the Inspector of Mines and Miners' representative (if present) that course is unnecessary.

The doctor, when present, shall examine every man engaged in rescue work before permitting him to go underground for a second spell of that work.

5. As soon as possible a base or bases shall be established in fresh air, but as near to the irrespirable zone or zones as safety permits. Each such base shall, if possible, be connected by telephone to the surface or to the shaft bottom. Whenever men are at work beyond the base there shall be stationed at the base as soon as possible the following: (*a*) Two men, of whom at least one should understand rescue appliances and first aid; (*b*) A spare brigade with rescue apparatus and ready for immediate service; (*c*) One or more oxygen revivers, stretchers and birds.

Captain or Leader of a Rescue Brigade.

6. The leader shall not permit the brigade to go underground until he has received clear instructions from the Manager or from the person acting on the Manager's behalf; and, unless the leader knows the route thoroughly, he shall take underground a plan on which the route is clearly marked.

7. The leader shall not engage in manual work. He shall give his attention solely to directing the brigade and to maintaining its safety. He shall examine the roof and supports during the journey inbye and, if there is any likelihood of a fall, he shall not proceed until the brigade has made the place secure. He shall not take the brigade through any passage less than two feet high and three feet wide, except in a case of urgent necessity.

8. When the atmosphere is clear, the leader shall, when passing the junction of two or more roads, clearly indicate the route by means of arrow-marks in chalk. When the atmosphere is thick with smoke the leader shall see that a life-line is led in from fresh air, and shall not allow any member of the brigade to move out of reach of that line; or, if that course is impracticable, he shall not proceed until every road branching from the route is fenced across the opening.

9. Before proceeding underground the leader shall test, or witness the testing of, every rescue apparatus of the brigade. He shall check the equipment of his party, and, immediately before entering irrespirable air, make sure that every apparatus is working properly.

10. When using rescue apparatus the leader (who shall carry a watch) shall read the pressure of the compressed oxygen every 20 minutes, or thereabouts, and shall commence the return journey in ample time. In travelling he shall adapt the rate to that of the slowest member.

MEMBERS OF RESCUE BRIGADES.

11. Members of brigades shall, in general, use the prescribed signals in communicating to one another.

12. In travelling with rescue apparatus, each member of the brigade shall keep the place given him when numbering off. If the pace is too quick, or if distress is felt for any reason, the member shall at once sound the distress signal.

13. No person shall commence a second or subsequent spell of work in bad air without being examined and passed by a doctor, if present, or by the rescue station instructor or other competent person if the doctor be not present.

V. Schemes of Training and Practice approved by the Secretary of State.

I hereby approve the following schemes of training and practice for the purposes of the General Regulations relating to rescue work made under the Coal Mines Act, 1911 :—

PART I.—SCHEME UNDER GENERAL REGULATIONS OF 19TH MAY, 1914.

(a) *Central Rescue Corps.*

The course of training shall consist of instruction and practices as hereinafter set out, and shall be continued until all the individuals comprising the corps are reported by the instructor to be efficient :—

(A) Instruction as to (i) the construction, use, repair and maintenance of the type or types of breathing apparatus provided for the corps, and of smoke helmets ; (ii) the use of methods and apparatus for reviving men ; (iii) the reading of mine plans ; and (iv) the properties and detection of noxious and inflammable gases which may be found in coal mines.

(B) Practices—not less than 12 in number for each member—with breathing apparatus under conditions so devised as to represent those likely to be encountered in underground operations requiring the use of breathing apparatus. In respect of these practices the following rules shall apply :—

(1) The practices shall be carried out by at least five members of the corps at one and the same time.

(2) The training shall commence with practices carried out in ordinary air and shall progress gradually to practices carried out in a hot or irrespirable atmosphere.

(3) Each practice shall last at least two hours (unless in the opinion of the instructor it is desirable in the interests of safety, to curtail the practice in respect of any member of the corps, or of the corps as a whole), and at some of the practices the breathing apparatus shall be worn continuously during the practice.

(4) The practices shall comprise the following operations :—

(*a*) Raising by means of a rope and pulley, a weight of 56 lb. to a height of six feet.
(*b*) Walking continuously at a fair pace for half-an-hour.
(*c*) Building and removing temporary stoppings of stone, brick, sandbags, brattice cloth, or other materials, and carrying the materials required for the same over a distance of at least ten yards.
(*d*) Removing débris in confined spaces as representing the clearing of a fall of roof.
(*e*) Setting timber or other roof supports.
(*f*) Carrying, pushing or pulling on a stretcher a live person or dummy body weighing 150 lb. along the length of the gallery, and through an opening 2 feet high by 3 feet wide and 4 yards long.
(*g*) The rapid establishment of telephonic communication.

(5) A record shall be kept of the date and character of each practice attended by a member of the corps, and the condition of each man after the practice, and, if anything abnormal is observed, it should be stated whether it is due to a defect of the apparatus or to the man himself.

(b) *Men from Individual Mines.*

The course of training shall consist of instruction and practices as hereinafter set out, and shall be continued until the individual is reported by the instructor to be efficient :—

(*a*) The same instruction as in the scheme for the Central Corps.

(*b*) Practices with breathing apparatus under conditions so devised as to represent those likely to be encountered in underground operations requiring the use of breathing apparatus. In respect of these practices the following rules shall apply :—

(1) Each man shall undergo at least twelve practices in the first year. The training shall commence with practices carried out in ordinary air and shall progress gradually to practices carried out in a hot or irrespirable atmosphere.

Not more than eight nor less than five men shall take part in any practice, but if five men do not attend on any occasion the number may be made up by members of the Central Corps.

(2) Each practice shall last at least two hours (unless, in the opinion of the instructor, it is desirable, in the interests of safety, to curtail the practice in respect of any member of the set, or of the set as a whole), and at some of the practices the breathing apparatus shall be worn continuously during the practice.

(3) In the case of men coming from mines where smoke helmets are kept, two additional practices with smoke helmets shall be given.

(4) The practices shall comprise the same operations as are specified above for the Central Corps.

(5) After being reported to be efficient, each man shall undergo at least one practice with breathing apparatus each quarter, which shall be carried out in a hot or irrespirable atmosphere.

(6) A record shall be kept of each person undergoing training or practice, the date and character of each practice attended, and the condition of each man after the practice, and, if anything abnormal is observed, it should be stated whether it is due to a defect of the apparatus or to the man himself.

PART II.—SCHEME UNDER THE GENERAL REGULATIONS OF 10TH JULY, 1913.

The course of training shall consist of instruction and practices as hereinafter set out, and shall be continued until all the members of the brigade are reported by the instructor to be efficient :—

(A) Instruction in the subjects mentioned in Regulation 140 (*d*) (iii).

(B) Practices—not less than 12 in number for each member—with breathing apparatus under conditions so devised as to represent those likely to be encountered in underground operations requiring the use of breathing apparatus. In respect of these practices the following rules shall apply :—

(1) The practices shall, as far as possible, be carried out by each brigade as such, *i.e.*, by all members of the brigade at one and the same time.

(2) The training shall commence with practices carried out in ordinary air, and shall progress gradually to practices carried out in a hot or irrespirable atmosphere. Each practice shall last at least two hours (unless, in the opinion of the instructor, it is desirable, in the interests of safety, to curtail the practice in respect of any member of the brigade or the brigade as a whole), and at some of the practices breathing apparatus shall be worn continuously during the practice.

(3) The practices shall comprise the same operations as are specified in Part I for a Central Rescue Corps.

(4) A record shall be kept of each person undergoing training, the date and character of each practice attended, and the condition of each man after the practice, and, if anything abnormal is observed, it should be stated whether it is due to a defect of the apparatus or to the man himself.

R. MCKENNA,
One of His Majesty's Principal
Secretaries of State.

HOME OFFICE.
18*th January*, 1915.

VI. Test for Leakage of Breathing Apparatus, prescribed by the Secretary of State.

In pursuance of No. 14 of the General Regulations made under the Coal Mines Act, 1911, and dated 30th July, 1920, I hereby prescribe that the test for leakage to be used for the purposes of that Regulation shall be as follows :—

The apparatus, before being taken below ground, shall be completely immersed in water fully distended and (except in the case of apparatus supplied with liquid air or oxygen) with the oxygen supply turned on ; and while so immersed shall be well shaken and shall be closely examined in every part for leakage by the Superintendent of the Rescue Station or by one of the Rescue Station Instructors or by the leader of the Brigade.

E. SHORTT,
One of His Majesty's Principal
Secretaries of State.

WHITEHALL,
21*st August*, 1920.

VII. Test for Breathing Apparatus, prescribed by the Secretary of State.

In pursuance of Nos. 15 and 16 of the General Regulations made under the Coal Mines Act, 1911, and dated 30th July, 1920, I hereby prescribe that the test to be used for the purposes of these Regulations shall be as follows :—

(*a*) The apparatus shall be tested for leakage in the manner prescribed for the purposes of Regulation 14.

(*b*) In the case of apparatus supplied with oxygen under pressure, the pressure in the oxygen cylinder shall be observed.

(*c*) In the case of apparatus supplied with oxygen under pressure, the rate of delivery of the oxygen shall be measured by a flowmeter, and where that rate is capable of being adjusted by the wearer of the apparatus, it shall be measured over the whole range of adjustment.

(*d*) In the case of a relief valve which operates automatically, the pressure at which it discharges shall be measured.

(*e*) The apparatus shall be carefully examined in respect of its general condition, and particular attention shall be given to any delicate parts such as the reducing valve.

E. SHORTT,
One of His Majesty's Principal
Secretaries of State.

WHITEHALL,
21*st August*, 1920.

VIII. Physical and Medical Test prescribed by the Secretary of State for Members of Rescue Corps and Rescue Brigades.

In pursuance of No. 18 of the General Regulations made under the Coal Mines Act, 1911, and dated 30th July, 1920, I hereby prescribe that the physical and medical test to be used for the purposes of that Regulation shall be as follows:—

(*a*) The person to be tested shall undergo some form of hard physical exertion[1] for not less than 15 minutes, and shall not be passed unless he is found by the superintendent of the station to have sustained the exertion without distress or undue fatigue.

(*b*) He must be certified by a duly qualified medical practitioner, after thorough examination, to be free from any organic disease or weakness and to be fit for undertaking rescue work in a mine.

E. SHORTT,
One of His Majesty's Principal Secretaries of State.

WHITEHALL.
21st August, 1920.

IX. List of Societies or Bodies approved by the Secretary of State for the purpose of granting Certificates of Proficiency in First Aid.[2]

The Secretary of State is advised that only certificates obtained subsequently to the date of approval can be considered as qualifying for the purposes of the Regulations and Rules.

Name of Society or Body.	*Date of Approval.*
Birmingham University	5th June, 1915.
British Red Cross Society..	11th May, 1915.
Glamorganshire Education Committee ..	2nd February, 1915.
Heriot-Watt College, Edinburgh	9th February, 1915.
St. Andrew's Association	10th July, 1913.
St. John Ambulance Association.. ..	10th July, 1913.

[1] It is suggested that ability to walk or run a distance of 1¼ miles in 15 minutes might be regarded as a suitable test for this purpose.

[2] See No. 148 of General Regulations dated 10th July, 1913; No. 1(a) of the General Regulations dated 19th May, 1914; and Regulation 24 of the General Regulations dated 30th July, 1920.

APPENDIX II

CONDITIONS OF EMPLOYMENT AND QUALIFICATIONS OF CANDIDATES REQUIRED AT A LARGE RESCUE STATION.

Sir,—With reference to your application for an appointment in the above Brigade, I herewith transmit you the subjoined Form, which you will get properly filled in, and forward same to me ; when, if found necessary, you will receive notice to attend for an interview and medical examination.

I am, Sir,

Yours faithfully,

.....

CHIEF OFFICER.

To Mr. .....

Of .....

QUALIFICATIONS.

The following qualifications are indispensable, and no candidate should make application who does not possess them.

1st—The age to be above 21 years and under 30 years. Candidates who have joined the Army and Navy may be admitted over the age of 30 years (12 years' Service men). Candidates of exceptional qualifications may be admitted under the age of 21 years.

2nd—To stand 5 feet 5 inches, without Shoes, and to have a chest measurement of at least 36 inches, under clothes.

3rd—To read and write well, to have a fair knowledge of English Grammar and Arithmetic, and to be generally intelligent.

4th—To be of a strong constitution and to pass a very searching examination by the Brigade Doctor (special Medical Form).

NOTE.—A knowledge of Mining is an advantage, but not essential, as successful Candidates will be sent to local collieries for experience (see Conditions of Employment).

PARTICULARS RELATING TO HEALTH.

Have you ever had a fit? .....

Have you ever spat blood? .....

Have you a cough every winter?.....

Have you ever had Rheumatism or Rheumatic Fever?.....

Have you ever been an In-patient of a Hospital or Infirmary?

.....

(*State the name of the Hospital or Infirmary, the date, and your illness on each occasion*).....

Have you ever been off work for more than a week on account of ill-health?.....

(*State the nature of the complaint on each occasion*).....

Candidates for the Brigade must be free from any bodily complaint, of a strong constitution, and equal to the performance of Brigade Duties.

The bodily complaints for which Candidates are most frequently rejected are as follows:—Rupture, Flat-foot, Varicose Veins, Tumours, Skin Diseases, Stiffness of Joints, Cough, Narrow Chest, Weak Sight, Deformities of the Face, and Fits.

Persons who believe themselves to be labouring under these, or any other bodily imperfections or diseases, had better not present themselves as Candidates.

The Brigade Doctor alone is responsible for the Medical Examination of all Candidates for this Brigade, and the Medical Certificate of any other practitioner cannot therefore be accepted. A Candidate may be considered unfit for the Service and be rejected, without any reason being assigned.

BRIGADE DOCTOR'S CERTIFICATE.

I HEREBY CERTIFY *that I have examined*..... *a Candidate for an appointment as Fireman in the*..... .....*Fire and Rescue Brigade, as to his state of health, general constitution, and physical development, and I consider him*.....*for Brigade Duty.*

(*Signature*).....

BRIGADE DOCTOR.

DECLARATION OF CANDIDATE.

Name in full (Surname).....(Christian Names).....

Full Postal Address of Present Residence.....

.....

Age.....Date of Birth.....Where born.....

Height....Feet....Inches, without Shoes. Weight..stones..lbs.

Chest measurement (next to skin)....inches. Nationality.....

Eyes, Colour of....Hair, Colour of.....Complexion.....

Married or Single; state Family and Dependencies (if any)

.....

Present Trade or Calling.....

WITH WHOM EMPLOYED FOR THE LAST FIVE YEARS.

Name of Firm.	Address.	How long Employed.	Nature of Employment.

If the Candidate has been in the Army, Navy, Police, Railway, or any Public Service, he must state here the length of time employed, with full particulars.....

.....

.....

.....

Date of leaving last Employment.....

Education .....

Qualifications .....

.....

.....

.....

.....

Do you hold an Ambulance Certificate and are you willing to take up Ambulance Work ?..... .....

Have you had any practical experience in Mining and Rescue Work ? If so, state full particulars.....

.....

Can you drive a Motor Car ?.....

Has your Driving Licence been endorsed ?.....

Have you been Medically Examined lately, and if so, with what results ? .....

References (copies of Testimonials to be attached).....

.....

.....

*I hereby declare that the above Answers were inserted by me on the.....day of.....*19...., *and that they are true and full replies to the several questions above specified.*

Signature .....
Occupation .....
Residence .....

The above Examination and Declaration were filled up by the Candidate in my presence, this.....19.....

Signature .....
Occupation .....
Residence .....

I HEREBY UNDERTAKE TO OBSERVE THE CONDITIONS OF SERVICE OF THE
FIRE AND RESCUE BRIGADE AND TO OBSERVE ALL NEW RULES AND REGULATIONS WHICH MAY BE MADE THROUGH BRIGADE ORDERS DURING THE TIME I AM IN THE BRIGADE'S EMPLOY. I HAVE INSPECTED A COPY OF THE BRIGADE ORDERS IN THE DUTY-ROOM AT THE STATION.

Signature of Candidate .....

Date.....19....

CONDITIONS OF EMPLOYMENT.

The following are the conditions upon which each man is appointed a member of the above Brigade, but the Rescue Committee and Chief Officer reserve to themselves the power to alter or annul any of such conditions and to adopt such new conditions as they from time to time deem expedient through Brigade Orders :—

(1) He shall, on appointment, deposit copies of his testimonials.

(2) His selection as a Candidate only constitutes him a Drill Class Fireman, and if during the time of his probation he does not qualify himself for promotion, the Chief Officer has power to dispense with his services forthwith.

(3) He shall devote the whole of his time to the duties of the Brigade, attend all fires—both surface and underground, colliery explosions, work salvage, repair appliances, keep the Station in repair, and discharge such other duties—as may be required from him.

(4) He shall serve and reside wherever appointed, and shall be subject to being removed from Station to Station when required.

(5) He shall promptly obey all orders from persons placed in authority over him, and shall conform to all Regulations now in force and that may hereafter be made.

(6) He shall not upon any occasion or any pretence whatever receive money, or any other gratuity, from any person or persons for any service as a Fireman, or in any other connection whatever with the Brigade, without the permission of the Chief Officer.

(7) He shall at all times appear in his complete uniform when on duty, unless permission be granted to wear plain clothes.

(8) He shall receive his pay weekly. In the case of a married man, free quarters, coal and light, are given. In the event of quarters not being attainable, an amount of money not exceeding.....per week will be given in lieu of same. Single men are pro-

vided with free quarters, bedding, and the necessary furnishings, for which they are held responsible.

(9) He will be supplied on appointment, and thereafter at such times as Brigade Orders allow, with the following articles :—

1 Fire Tunic.	1 Jersey.
1 Serge Jacket or Tunic.	1 Pair Fire Boots.
2 Pairs Trousers.	1 Pair Pit Boots.
1 Pair Overalls.	1 Helmet.
1 Cap with Ribbon.	1 Belt, Axe and Pouch.
2 Cap Covers.	1 Whistle.
1 Pit Cap.	1 Life-line.

(For other articles see Brigade Orders.)

(10) None of the above articles are to be considered at any time to belong to him ; he shall keep such articles in good order and repair, and should any injury be done to them he shall make good the same, injury in the service and necessary wear and tear excepted.

(11) A Fireman dismissed from the Brigade, or who resigns his office, shall immediately after dismissal or resignation, deliver up every article of dress and appointments which have been supplied to him. If any such articles or appointments have, in the opinion of the Chief Officer been improperly used or damaged, deduction from the pay then due to the Fireman shall be made sufficient to make good the damage or supply of new articles.

(12) He shall not quit the Brigade without giving or receiving 7 days previous notice (week ending Tuesdays, 5 p.m.).

(13) He shall be liable to instant dismissal, with forfeiture of pay, and arrears of pay, for Unfitness, Negligence, or Misconduct, independently of any other punishment provided by Law.

(14) He will be required to attend at a local Colliery, as arranged by the Chief Officer, for practical experience in mining.

APPENDIX III.

REPORT OF INSPECTION

Week ending.....19 .

Self-contained Breathing Apparatus.

No.	Type.	Particulars of Test.	Adjustments Made.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Oxygen Reviving Apparatus.

Type.		

Telephones.

Condition of Telephones, Reels and Cables .....

Number and Condition of Horns .....

Remarks :—

.....

.....

.....

I hereby certify that I have examined the above-mentioned in mines unless where otherwise stated.

OF RESCUE APPLIANCES.

.....*Station.*

No.	Type.	Particulars of Test.	Adjustments Made.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Smoke Helmets and Respirators.

Type.		

Breathing Apparatus Spares.....

Goggles, Number of..... *Liquid Air Containers*.....

Number and condition of Birds and Animals.....

.....

.....

.....

appliances, and deem them to be in a fit condition for emergency

Signed .....BRIGADESMAN.

Countersigned ..... OFFICER.

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